

**FINAL INTERMIM DATA REPORT**

**REAL-TIME CURRENT METER MOORING  
AT THE 106-MILE SITE:  
JANUARY 1989 THROUGH SEPTEMBER 1990**

Submitted to

**ENVIRONMENTAL PROTECTION AGENCY  
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## **1.0 INTRODUCTION**

### **1.1 BACKGROUND**

The 106-Mile Deepwater Municipal Sludge Dump Site (106-Mile Site), located southeast of New York (Figure 1), is the only United States ocean disposal site designated for dumping of sewage sludge. Evaluation of sludge disposal and of the fate and effects of sludge dumped at the 106-Mile Site has been conducted since 1986 under a monitoring plan developed and implemented by the Environmental Protection Agency (EPA, 1991a,b). In 1988, the United States Congress passed the Ocean Dumping Ban Act (ODBA), under which EPA, the National Oceanic and Atmospheric Administration (NOAA), and the United States Coast Guard (USCG) jointly developed a new 106-Mile Site monitoring plan (EPA, 1990). This interagency plan continues the monitoring and research activities of the EPA monitoring plan, which it supersedes. Tier 2 of the Joint Monitoring Plan addresses the short-termed behavior, transport, and impact of sludge within the 106-Mile Site and in the immediate area surrounding the site both in terms of permit compliance and impact assessment. Tier 3 of the Joint Monitoring Plan addresses the transport and fate of sludge in the long term and the farfield. As part of both Tier 2 and Tier 3 studies, beginning under the EPA Monitoring Plan (EPA, 1991a,b) and continued under the Joint Monitoring Plan (EPA, 1990), a long-term mooring was deployed adjacent to the 106-Mile Site to measure near-surface currents and meteorological conditions, and transmit these data via satellite to shore in near real-time. The mooring program through September 1990 consisted of four deployments of the real-time mooring during the 21-month period beginning January 1989. The mooring was redeployed in October 1990, but those data are not presented here.

Under Tier 2 activities, near-surface current data from the mooring were used during plume-tracking measurements made during the summer of 1989 to aid in plume tracking and to allow estimates of sludge dispersion and transport (Battelle, 1991). In addition, the continuous record of currents from the mooring was used in conjunction with the seasonal plume-tracking data to estimate the interseasonal behavior and near-field fate of sludge plumes. EPA Region II has also used the meteorological and wave data in near real-time to monitor permit compliance under emergency dumping conditions. With these activities completed, it is the intention of this report to present the data acquired during the first 21 months of the mooring deployment for use in Tier 3 studies of the farfield fate of sludge.

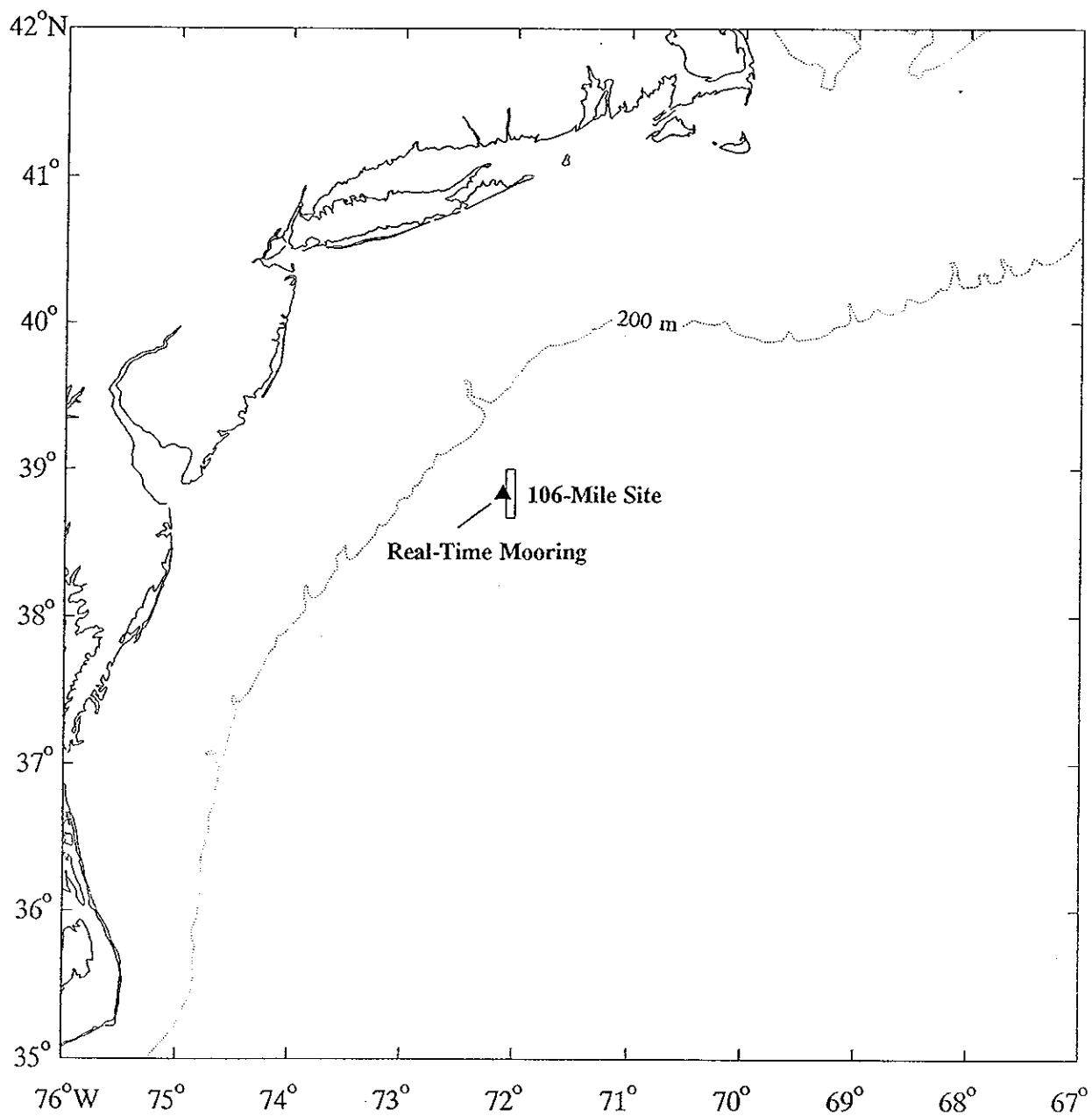


Figure 1. Map of Mid-Atlantic Bight showing location of the 106-Mile Site and the real-time mooring.

Tier 3 monitoring and research activities are intended to estimate the long-term fate of sludge due to transport, mixing, and sinking (EPA, 1990). To address these questions, various studies have been conducted, including a satellite-tracked drifting buoy program (Battelle, 1991b), a satellite surface thermal imagery program (Battelle, 1991c,d), a large moored sediment-trap program (Battelle, 1991e), and a numerical modeling program. The real-time mooring program was continued under Tier 3 to provide current, temperature, and meteorological data that will be used jointly with data resulting from these and other programs being conducted under the Joint Monitoring Plan (EPA, 1990). For example, the trajectories of satellite-tracked drifters will be used to estimate water-mass movement in the vicinity of the 106-Mile Site. Interpretation of these Lagrangian data (i.e., particle-following) will be aided by the continuous record of Eulerian velocities (i.e., fixed in space) from the real-time mooring. The satellite imagery will be used to infer the movement of water masses throughout the Mid-Atlantic Bight from weekly images of ocean surface temperature. The continuous, hourly record of currents and temperature from the real-time mooring will be helpful in interpreting these data. The current-meter data from the sediment-trap moorings will be augmented by the data available from the real-time mooring. For the modeling effort, the real-time mooring will provide a long-term record of currents at the Site for model calibration.

## **1.2 SITE DESCRIPTION AND REGIONAL CIRCULATION**

The 106-Mile Site is located southeast of New York in the Slope Sea of the Mid-Atlantic Bight. It is approximately 120 nmi from New York Harbor and 130 nmi due east of Cape May, New Jersey. It is only about 30 nmi east of the outer edge of the continental shelf (the 200-m isobath in Figure 1), located over the continental slope, the area of steeply sloping bathymetry that marks the edge of the continental land mass. The water depth varies between 2300 and 2800 m as the bottom slopes sharply southeastward.

The real-time mooring was deployed in approximately 2600 m of water just west of the Site. (A position outside the Site was chosen to avoid barge traffic.) Figure 2 shows the exact anchor position during each of the four deployments, A through D. The initial deployment was made in January 1989, and three redeployments constitute the mooring record through September 1990 that is presented in this report.

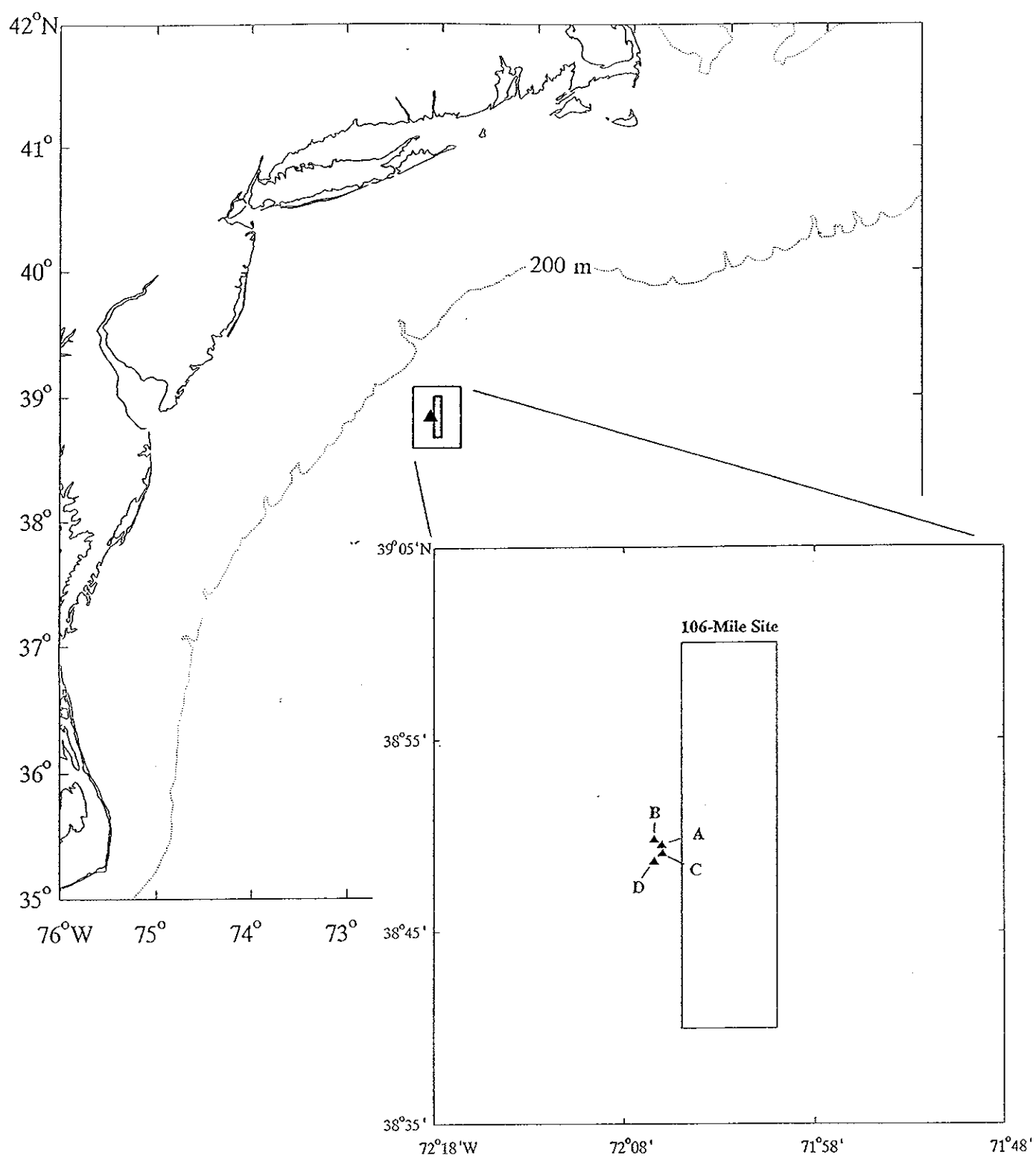


Figure 2. Map of 106-Mile Site showing location of real-time mooring deployments.

Subsequent mooring servicing continued until June 1991, when all equipment was recovered. Data from the later period will be included in a second data report.

The general circulation of the near-surface waters of the continental shelf and slope sea of the Mid-Atlantic Bight are relatively well understood (see, for instance, Beardsley *et al.*, 1976). The main features (shown in Figure 3) consist of weak southwestward flow over the continental shelf, strong northeastward flow of the Gulf Stream, and a weak slope sea gyre (Csanady and Hamilton, 1988). The southwestward flow over the continental shelf and the marginal waters of the slope sea are driven primarily by the large-scale wind stress and heat-flux patterns over the western North Atlantic (Beardsley and Boicourt, 1981). Long-term current-meter moorings on the continental shelf have provided good statistics on the mean flow on the shelf (Beardsley *et al.*, 1976), but measurements in the slope sea are sparse. In the Slope Sea, the mean flow is frequently perturbed by warm-core rings and smaller-scale eddies shed by the Gulf Stream. Their effect on the mean circulation is not well quantified. Neither are the effects of the Gulf Stream on the gyre. The latitude of the sharp eastward turn of the southwest corner of the gyre near Cape Hatteras varies considerably, probably due to changes in the location of the Gulf Stream. The strength of the gyre may also be a function of the Gulf Stream position, increasing as the Gulf Stream moves north (Bane *et al.*, 1988).

## 2.0 INSTRUMENTATION AND MEASUREMENTS

### 2.1 MOORING AND INSTRUMENTATION

The mooring program through September 1990 consisted of four deployments of the real-time mooring during the 21-month period beginning in January 1989. The mooring was again redeployed in October 1990, but those data are not presented here. The mooring was designed, fabricated, and maintained by Battelle Ocean Sciences. The configuration of the mooring for each of its four deployments is shown in Figure 4; Table 1 presents additional detail. The general configuration of the mooring included a 2-m-dia surface discus buoy with Argos satellite transmitter, current meters at 25 and 100 m depth, and a near-bottom acoustically operated release. A meteorological/wave package was added to the surface buoy in February 1990. All current meters recorded data internally. In addition, the near-surface current meter (25 m depth) relayed current and temperature data to the satellite transmitter for repackaging and

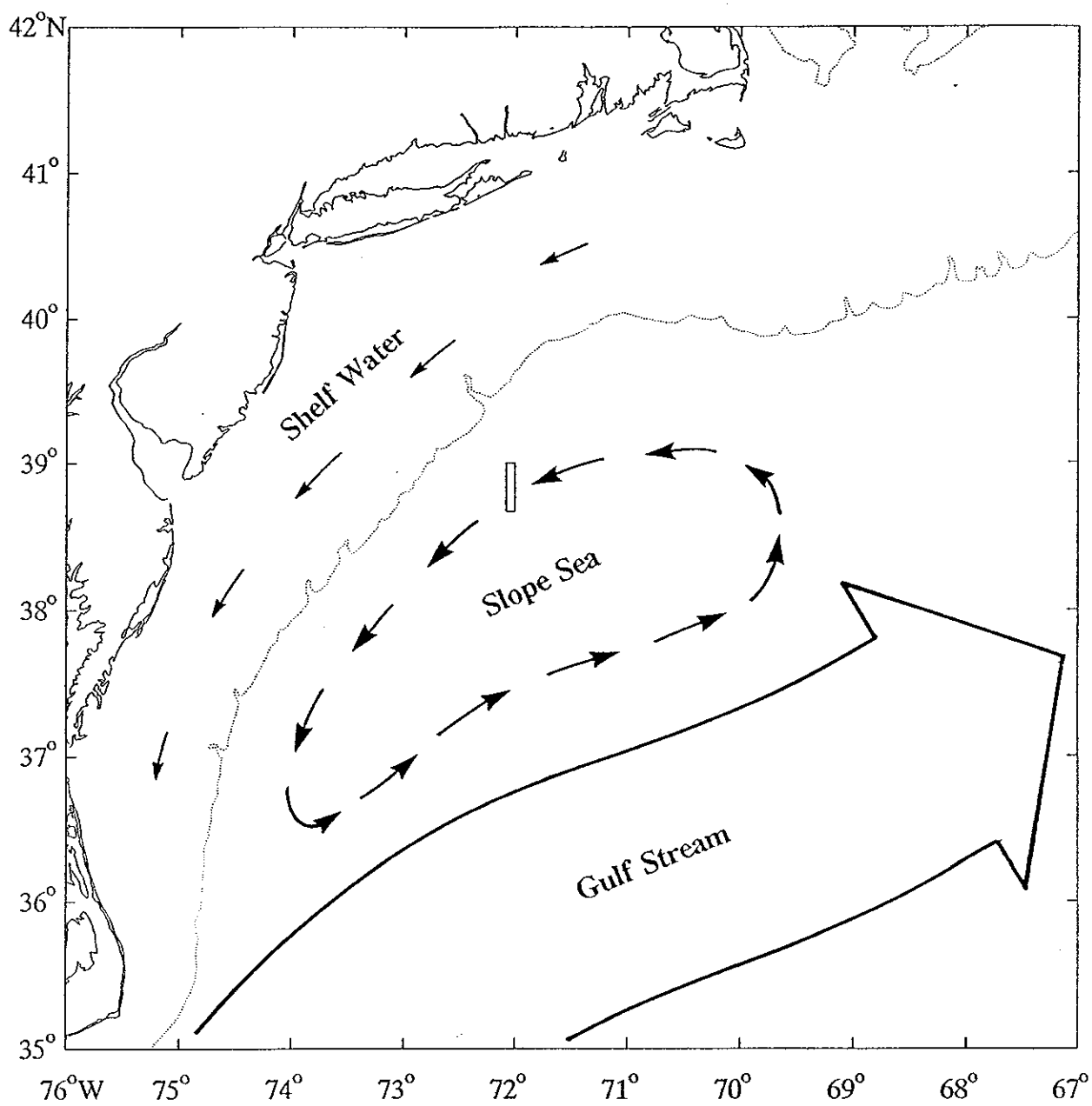


Figure 3. Illustration of regional circulation in the Mid-Atlantic Bight.

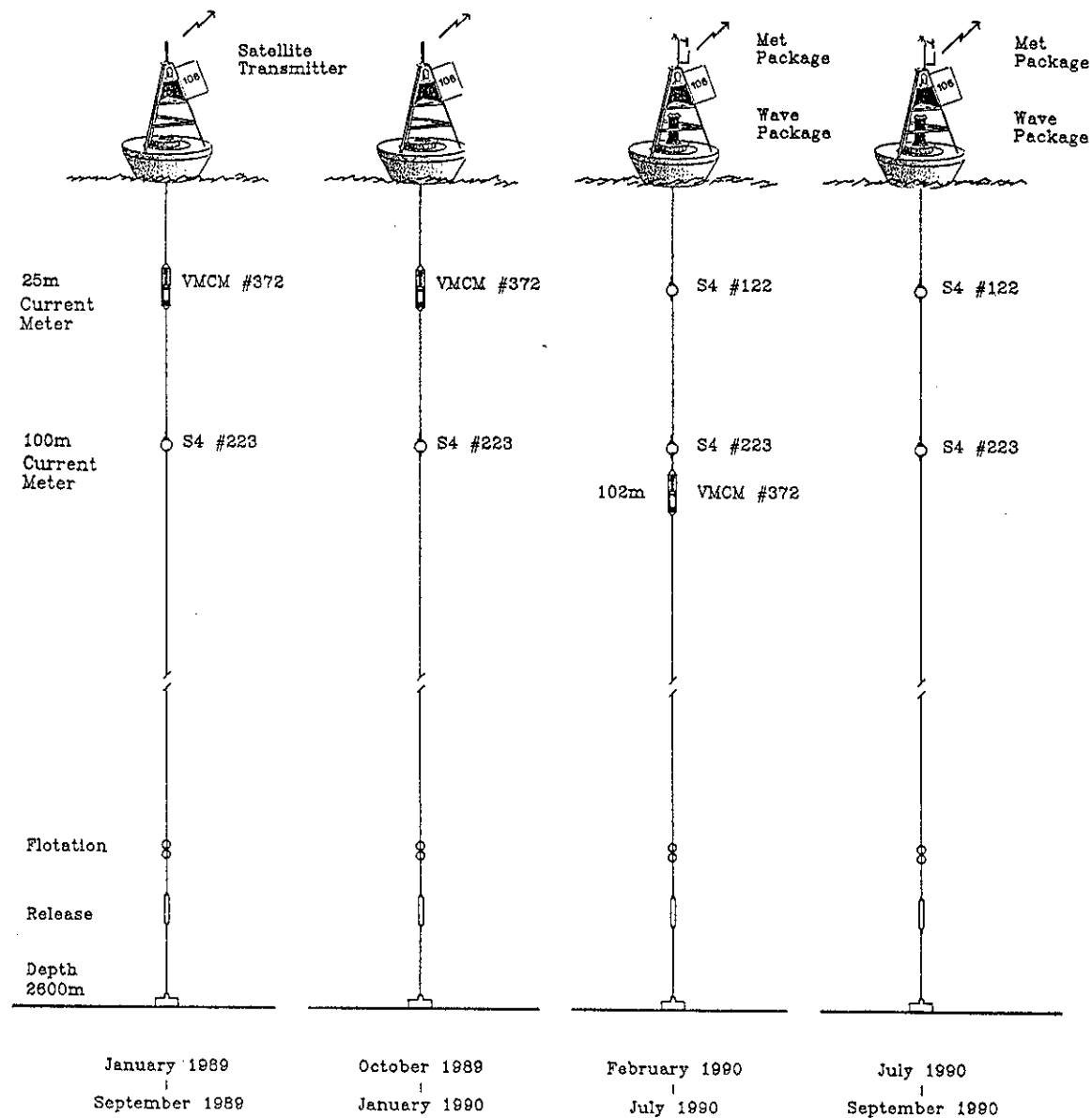


Figure 4. Configuration of moorings deployed at the 106-Mile Site.

retransmission to shore. A second Argos transmitter was installed with the meteorological/wave package to transmit those data separately. The mooring was deployed on station for all but three turnaround periods during the 21 months (see Figure 5). These turnarounds were required to periodically recover data and to refurbish instruments and mooring hardware. The turnaround in July 1990 was accomplished at sea, but the other two required returning the mooring to shore for more extensive refurbishing.

Two types of current meters were used during the life of the mooring: Interocean model S4 electromagnetic current meters (S4) and an EG&G propeller-type vector measuring current meter (VMCM). (Refer to Figure 5 for the deployment periods of each.) The S4s sample horizontal current velocity and temperature every 0.5 s, then once an hour, average the readings over a preset interval (typically 5 to 20 min) (see Table 1 for details). An internal compass resolves the instrument magnetic heading, and average east and north current components are recorded internally and relayed to the satellite transmitter where applicable. The VMCM on the other hand, continuously sums east and north vector components from two orthogonal propeller sensors. Like the S4, the VMCM then resolves instrument heading using an internal compass and internally records and/or relays the average velocity along with temperature.

Satellite data transmission was provided by Service Argos, a joint United States/French Government program that provides position tracking and environmental data transmission (at low data rates) anywhere on the surface of the Earth (Service Argos, 1988). Service Argos is a cooperative program between Centre National d'Études Spatiales (CNES, the French Space Agency), the National Aeronautics and Space Administration (NASA), and NOAA. Service Argos onboard packages are carried by two NOAA satellites in circular, polar orbit. These satellites orbit the earth every 102 min, or 14 times a day. They have a visibility area (i.e., footprint) with a 5000-km diameter on the surface of the earth over which they can receive signals from transmitters. Surface transmitters, the so-called user platforms, transmit radio frequency messages approximately every 90 s. Because footprint overlap increases with latitude, the mean number of daily passes over a position is a function of latitude. There are about 26 passes a day over the 106-Mile Site. However, during a satellite pass, user platforms that are located near the periphery of the footprint frequently cannot get a clean, repeatable transmission to the satellite, so that not all passes result in data transmission. For the Mid-Atlantic Bight and the 106-Mile Site, typically 10 to 12 data transmissions are obtained per day. A Bathymetry Systems, Inc., controller onboard the surface buoy, stored up to 5 h of current-meter data for relay to the transmitter. In this way, a continuous (albeit, redundant) stream of hourly current and water temperature data were transmitted. User platform data (and location) are stored in the satellite until it passes over an earth receiving station, at which time the data are downloaded to Service Argos computers for processing, storage, and dissemination. Then,

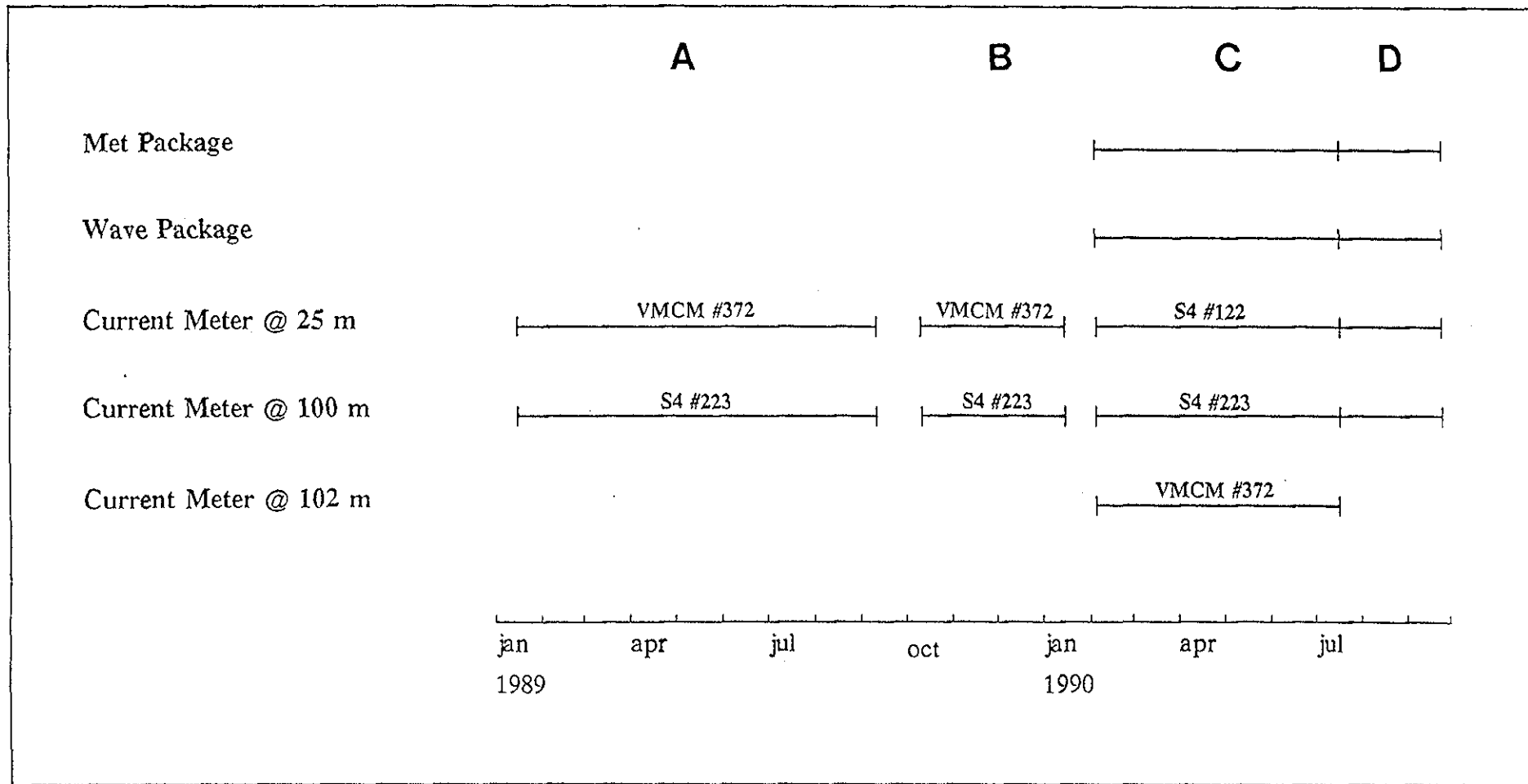


Figure 5. Deployment timeline of 106-Mile Site real-time mooring.

Table 1. Summary of current meter, meteorological, and wave measurement program.

Deployment Designation	Deployment/ Recovery	Position	Instrument	Instrument Depth (m)	Telemetry	Sensors	Sample Rate	# Days Operation/ Days Deployed	Data Return
A	1/19/89- 9/13/89	38°50.0'N 72°06.0'W	VMCM #372	25	✓	velocity temperature	20 min avg every hr	178/238 238/238	75% 100%
			S4 #223	100		velocity temperature	10 min avg every hr	238/238 238/238	100% 100%
B	10/13/89- 1/17/90	38°49.8'N 72°06.4'W	VMCM #372	25	✓	velocity temperature	20 min avg every hr	0/95 0/95	0% 0%
			S4 #223	100		velocity temperature	15 min avg every hr	95/95 95/95	100% 100%
C	2/7/90- 7/18/90	38°49.1'N 72°06.0'W	S4 #122	25	✓	velocity temperature	6 min avg every hr	6/161 6/161	4% 4%
			S4 #223	100		velocity temperature	20 min avg every hr	7/161 155/161	4% 96%
			MET PACKAGE	surface	✓	baro pressure air temperature wind velocity	10 min avg every hr	161/161 77/161 161/161	100% 48% 100%
			WAVE PACKAGE	surface	✓	accelerometer	17 min burst every hr	161/161	100%
D	7/19/90- 9/26/90	38°48.7'N 72°06.4'W	S4 #122	25	✓	velocity temperature	20 min avg every hr	69/69 69/69	100% 100%
			S4 #223	100		velocity temperature	20 min avg every hr	0/69 69/69	0% 100%
			MET PACKAGE	surface	✓	baro pressure air temperature wind velocity	10 min avg every hr	69/69 0/69 69/69	100% 0% 100%
			WAVE PACKAGE	surface	✓	accelerometer	17 min burst every hr	69/69	100%

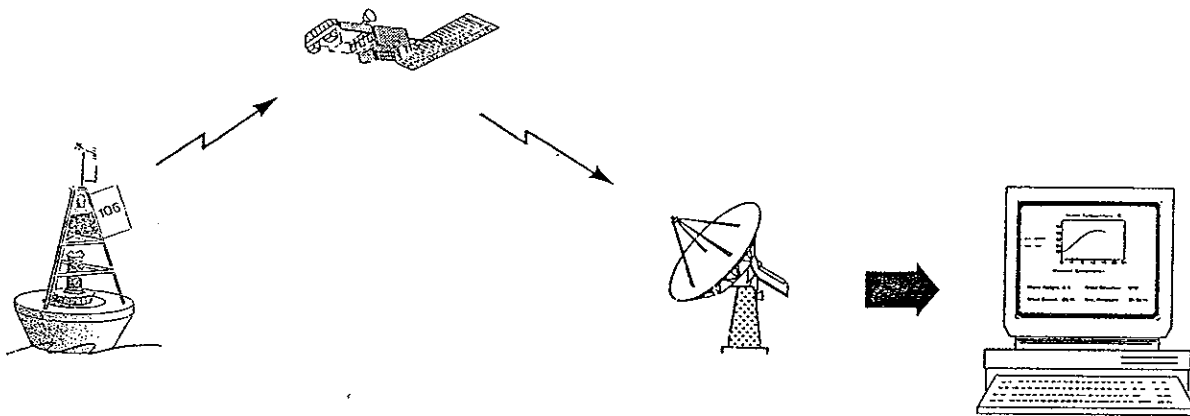
within about 3 h of the measurement, the data are available onshore via telephone (see Figure 6).

During deployments C and D, a Zeno-1600 Meteorological and Wave Data Acquisition System manufactured by Coastal Climate was installed on the surface buoy. This package included sensors for wind speed and direction, air temperature, barometric pressure, and buoy acceleration (wave height and period). The package also contained its own Argos satellite transmitter and controller.

## 2.2 DATA RECOVERY

The data return over the 21-month measurement program presented here was less than 100% due to a combination of electronic and mechanical failures. Overall, there were a total of 2230 sensor-days of operation out of 3172 sensor-days of deployment for a comprehensive data return of 70%. See Table 1 for the detailed breakdown of data return by instrument and sensor. The mooring hardware and instrumentation were subjected to an extremely hostile environment. The surface buoy experienced large accelerations during high winds and waves and these accelerations were coupled to the current meters and to the electromechanical cable connecting the current meters to the surface buoy. Moorings of this type deployed by other investigators have shown frequent, catastrophic failures (Frye, 1990), but the alternatives, e.g., acoustic telemetry or inductive systems, have yet to be made practical and reliable. Given the difficulties, a data return of 70% was within acceptable limits.

The VMCM experienced the most problems. Upon its recovery after deployment A, broken propeller blades were discovered. From the velocity time-series it was estimated that the propellers began to break on day 179 of the 238-day deployment period. This may have been caused by wave forces or perhaps by fishbite, but there is no way to tell for certain. The VMCM was serviced and redeployed for deployment B. Within hours of redeployment, the magnetic tape transport failed, which in turn caused the suspension of data relay to the satellite transmitter. Following deployment B, the VMCM was returned to the manufacturer, but the cause of the tape transport failure could not be determined. Consequently an S4 was rushed into service in place of the VMCM for deployment C. (As a test, the VMCM was deployed just below the S4 at 100 m, but the tape transport again failed to operate.)



**Figure 6. Illustration of data telemetry from surface buoy through Service Argos satellites to shore station PC.**

During deployment C, the communication cable between the S4 at 25 m and the surface buoy failed 6 days after deployment during a February storm. This shorted the S4, and drained power so that internal recording stopped soon after. The S4 at 100 m was damaged in the same storm; a severe impact shifted the magnetic coil assembly, breaking its electrical leads. In addition, the air-temperature sensor of the meteorological package apparently failed after 77 days during deployment C.

Although data telemetry made it possible to monitor the operational status of the upper current meter and meteorological/wave package in real-time, when problems arose EPA sometimes chose not to have the equipment serviced in order to minimize cost.

### 3.0 DATA PROCESSING PROCEDURES

Each current meter internally records a time series of perpendicular (orthogonal) current velocity components and temperature values in memory or on tape at a user-specified interval (given in Table 1). Preliminary data unpacking and quality assurance proceeds as follows. The current and temperature data from the current meters are transferred to disk with translation from internal instrument formats to calibrated engineering units. For both the S4 and the VMCM this is accomplished by using manufacturer software. At this point, start and stop times are compared with field logs to verify proper current-meter clock operation. The time-series are then truncated, beginning and end, to eliminate data recorded while the instruments were out of the water. Any gaps, wild points (pegged values), or outliers are identified and filled, if possible, using a cubic spline interpolation. The meteorological and wave data receive the same preliminary quality assurance, but no unpacking is required since data were recorded to disk during daily calls to Service Argos.

At this point "clean" versions of hourly time-series of current, temperature, meteorological, and wave data have been created and together with descriptive information they constitute the database of Battelle's MATLAB®-based physical oceanographic analysis software. Analytical routines in this library are then used for analysis of the data.

Current-velocity components are normally rotated into a coordinate system oriented parallel to the regional trend in the bathymetric contours. This coordinate system is identified here as along- and cross-shelf, referring to the mean orientation of the continental shelf that is roughly parallel to the bathymetric contours of the 106-Mile Site area. The along-shelf direction was chosen as directed along 45° T.

A 50-h low-passed (LP) filter (with a cosine taper) is applied to the clean hourly time series. LP filtering suppresses the amplitude of variability at frequencies greater than or equal to the diurnal frequency. The hourly and 50-h LP records and associated database attributes become the source time-series used in subsequent analyses.

For the present program, the standard set of analyses includes

- Raw data plots
- Statistical analysis including principal component axes analysis and bivariate statistical analysis
- Harmonic tidal analysis
- “Stick” or vector plots of the 50-h LP data
- Frequency spectral analysis

## 4.0 RESULTS

### 4.1 TIME-SERIES ANALYSIS

Time-series plots of the hourly current and temperature data are presented in Figures 7 and 8(a)-(c). Supplementary data are also included where available. These plots provide an overview of the measurements made during this study and are intended to show the general character of the current and temperature records for the 106-Mile Site. All records were sampled at 1-h intervals and rotated into true east and north components. The mean has not been removed. The current time-series show the characteristic signal of a combined tidal and low-frequency flow with a high-frequency (12-h period) variability superimposed on low-frequency variations having periods of days and weeks. The high-frequency variability includes the dominant semidiurnal (12-h period) tidal current, but is weak ( $< 10$  cm/s) compared to the low-frequency variations (as great as 60 cm/s). The raw meteorological and wave data for deployments C and D are presented in Figure 9. Note the high winds and waves present during several February storms, which accounts for the damaged current meters on deployment C.

Vector plots of the low-frequency currents are shown in Figures 10(a)-(d). Low-frequency currents were determined by low-pass filtering the data with a 50-h filter (half-amplitude at 50 h). This effectively removes any tidal variability from the current record. The current-velocity vectors are represented as sticks with a length corresponding to the flow speed and direction indicating the direction *toward* which the current flows. The along-shelf direction (chosen as northeast,  $45^\circ$  T) is toward the top of the page and cross-shelf (southeast) is to the right. From these vector plots, a moderate and persistent

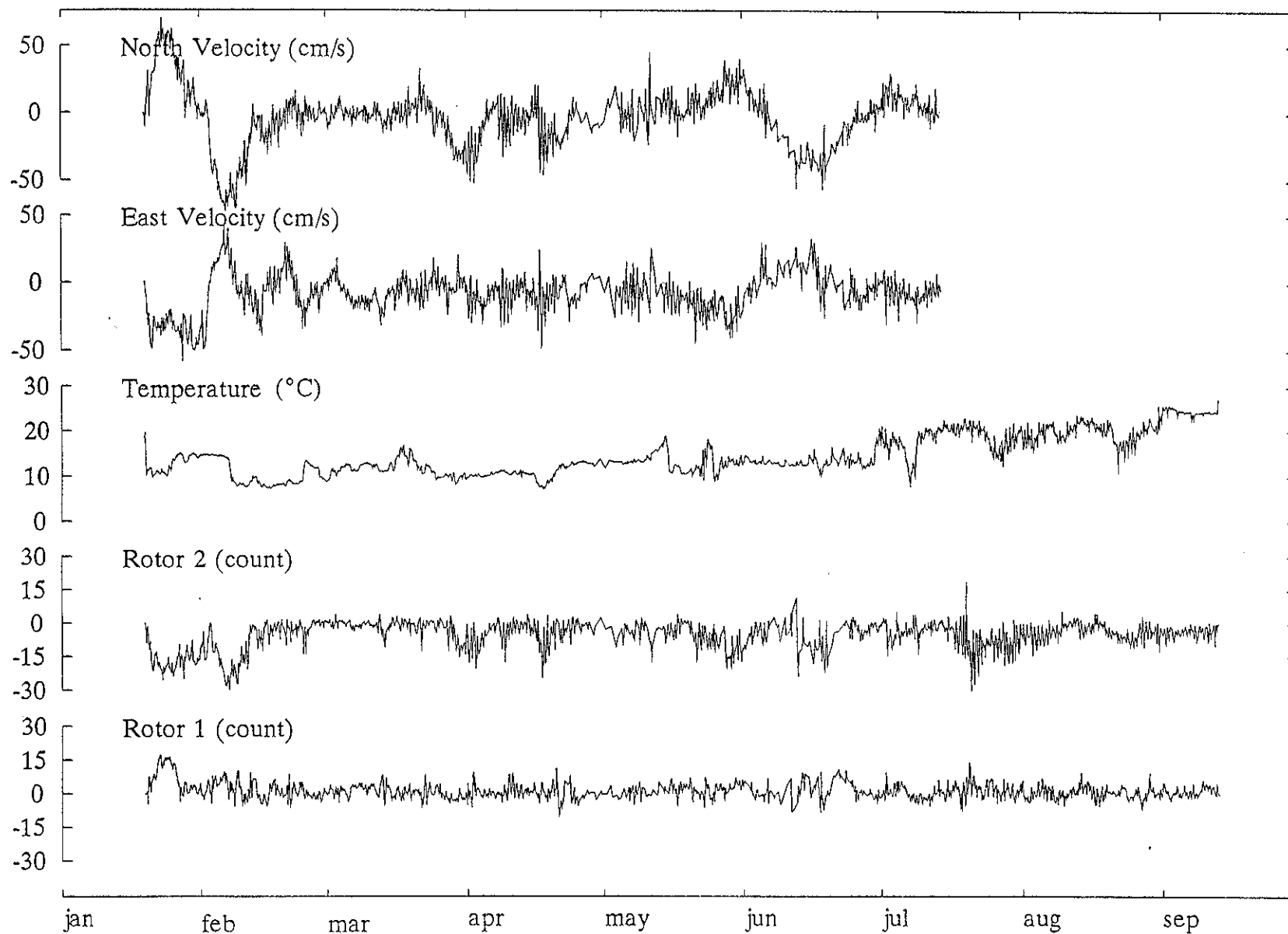


Figure 7. Hourly time-series of raw currents, temperature, and rotor counts.  
Deployment A at 25 m depth. January through September 1989.

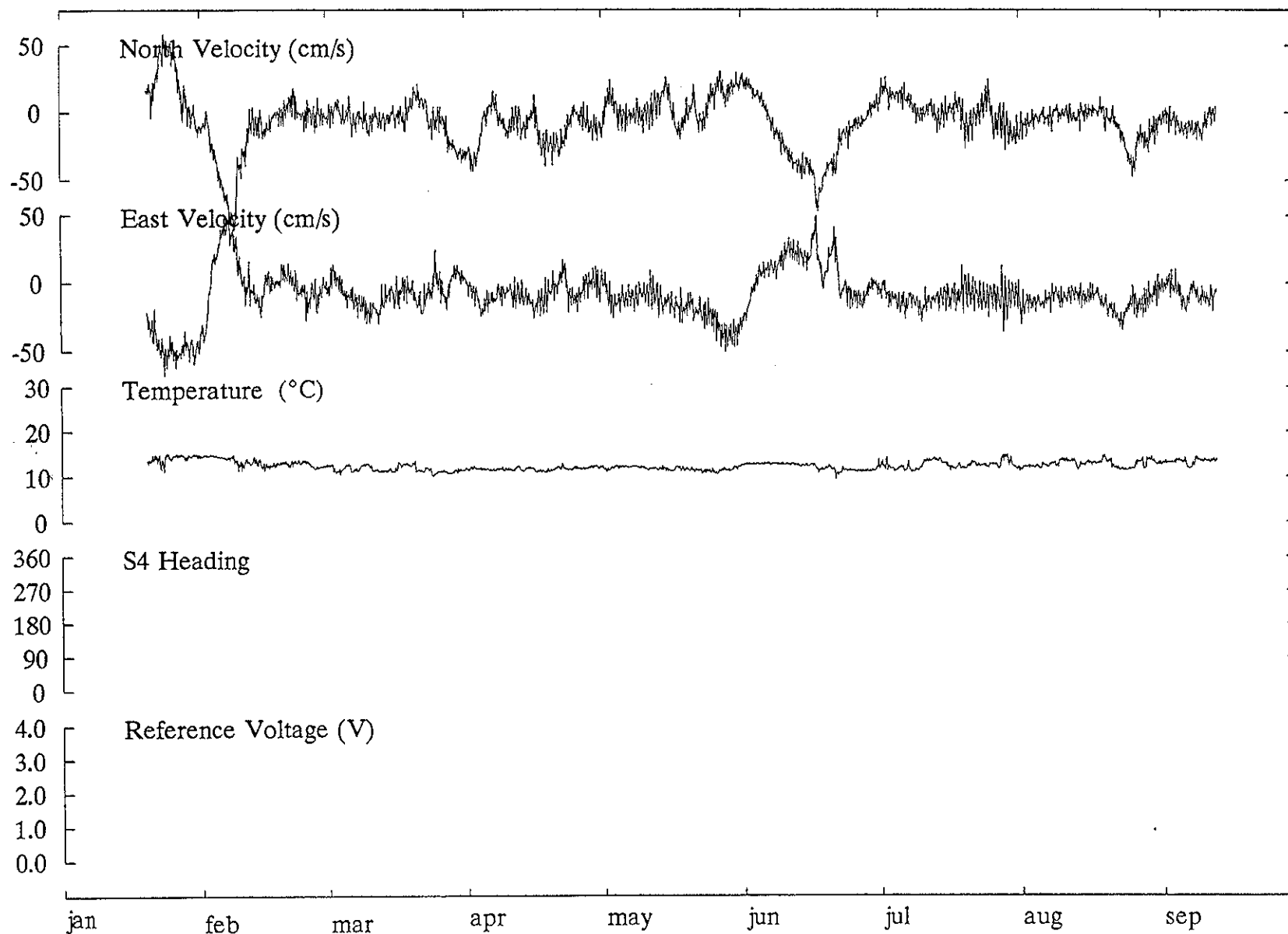
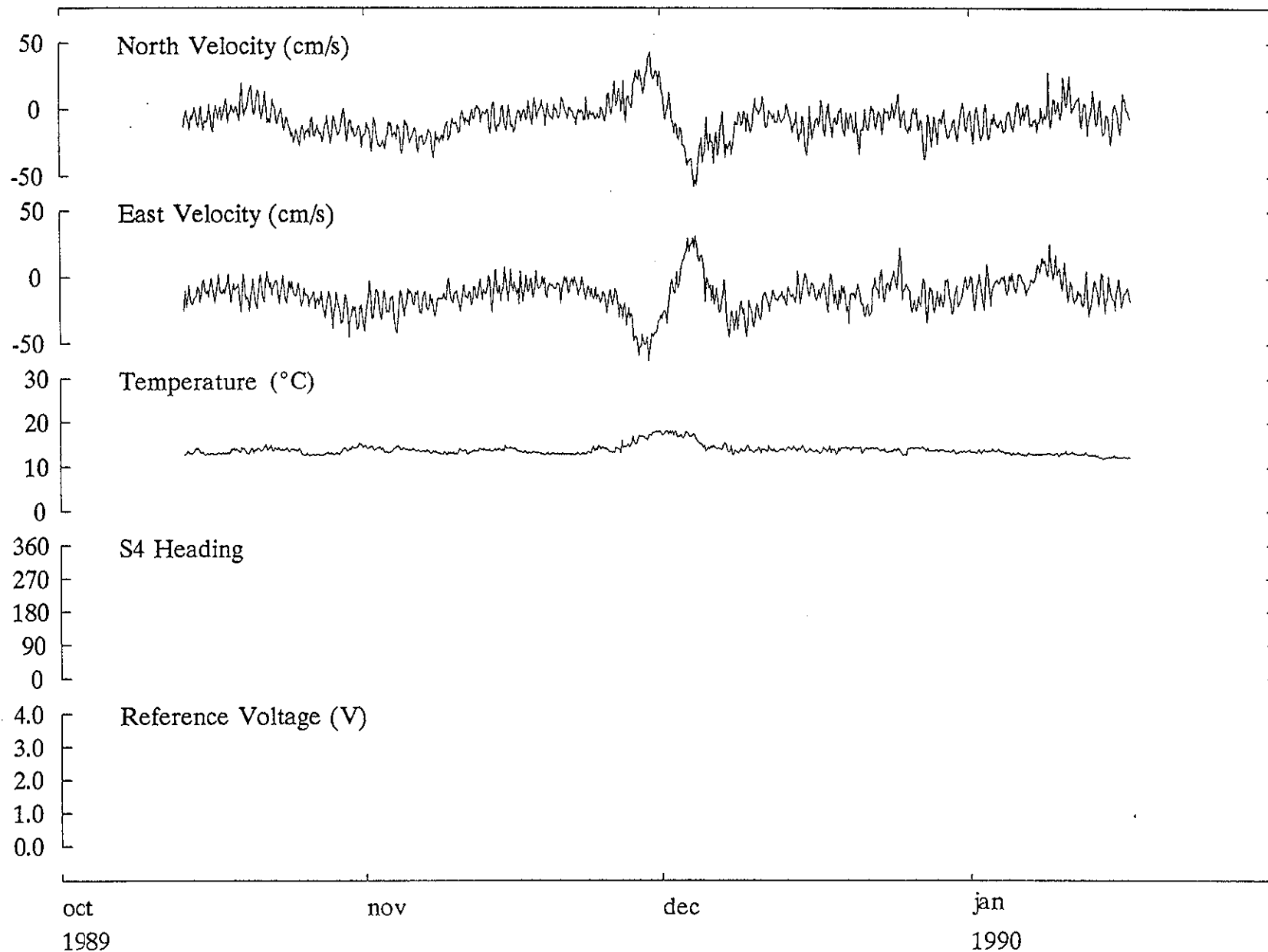


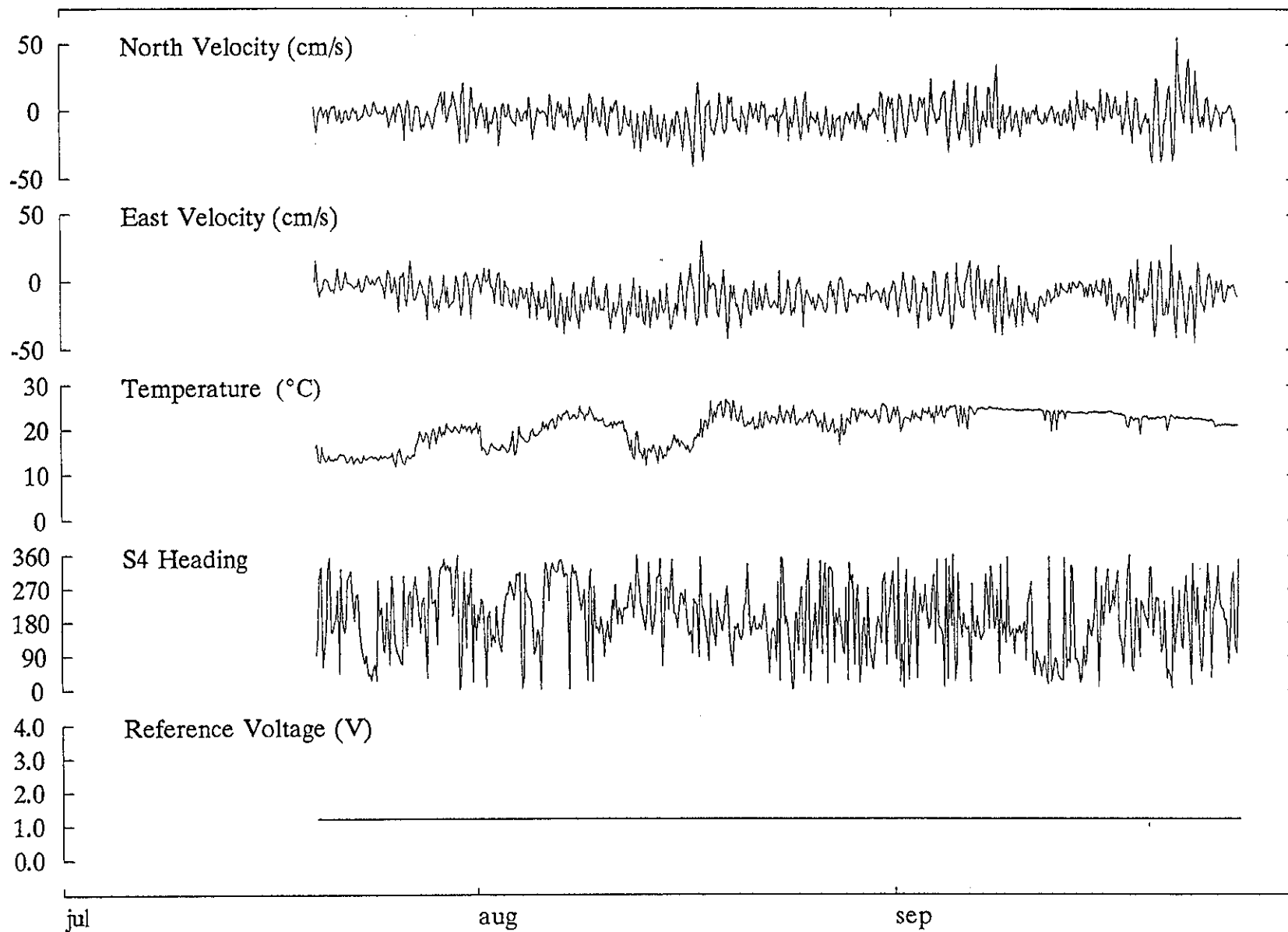
Figure 8. Hourly time-series of raw currents, temperature, instrument heading, and reference voltage.

(a) Deployment A at 100 m depth. January through September 1989.

Instrument heading and reference voltage were not recorded during this deployment.



**Figure 8. Hourly time-series of raw currents, temperature, instrument heading, and reference voltage.**  
**(b) Deployment B at 100 m depth. October 1989 through January 1990.**  
Instrument heading and reference voltage were not recorded during this deployment.



1990

Figure 8. Hourly time-series of raw currents, temperature, instrument heading, and reference voltage.  
(c) Deployment D at 25 m depth. July through September 1990.

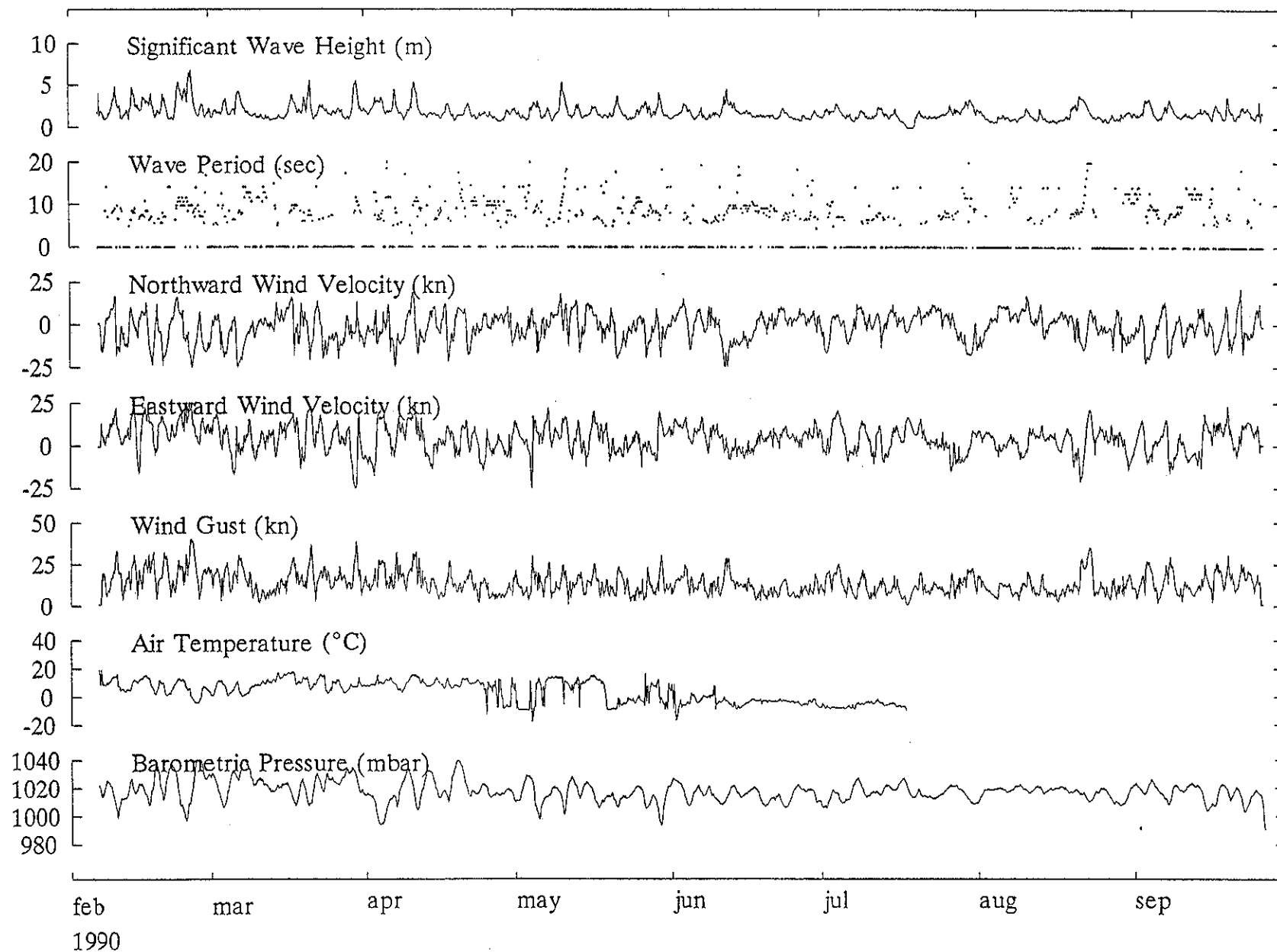


Figure 9. Hourly time-series of raw meteorological and wave data.  
Deployments C and D. February through September 1990.

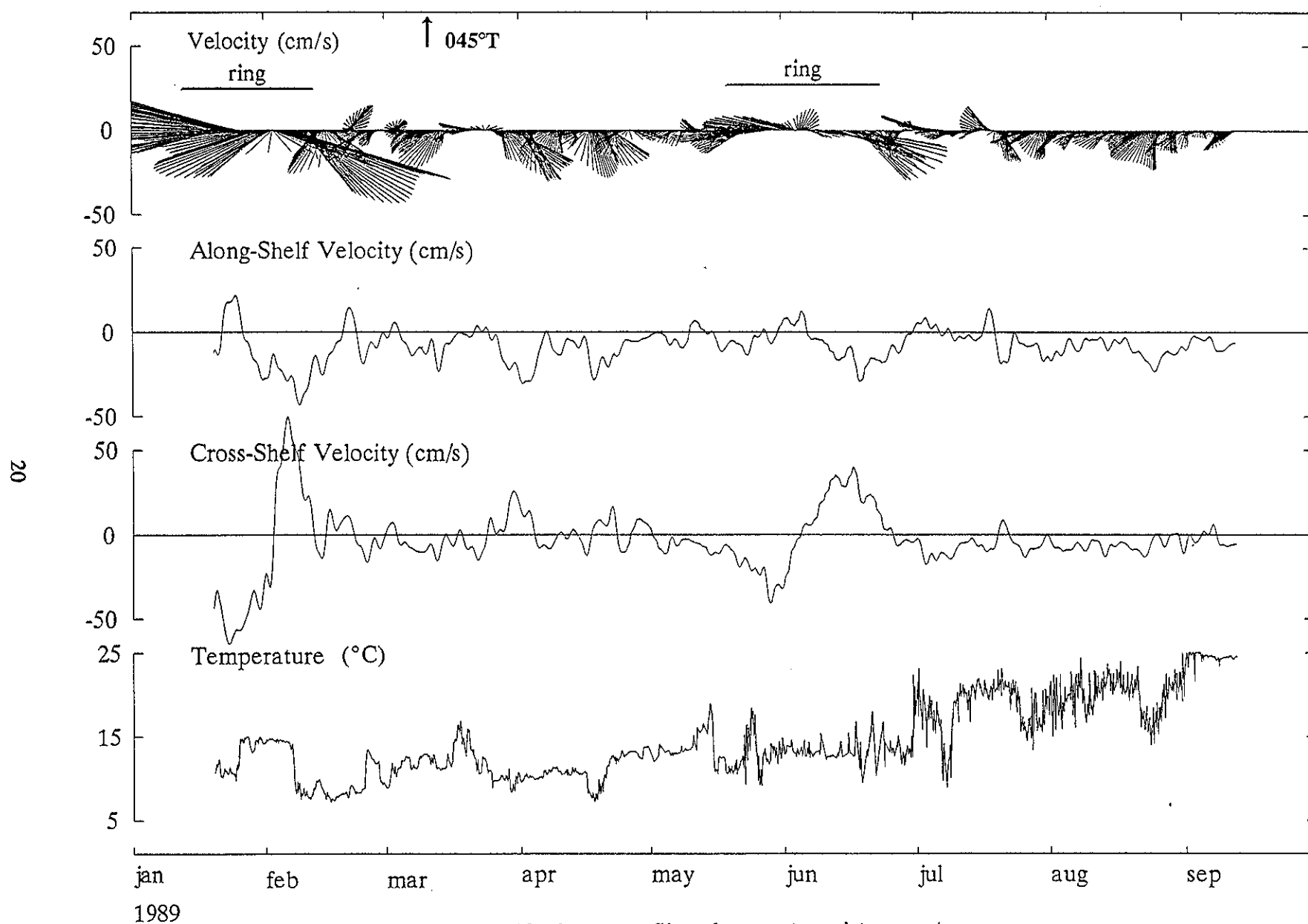


Figure 10. Low-pass-filtered currents and temperature.  
(a) Deployment A at 25 m depth. January through September 1989.

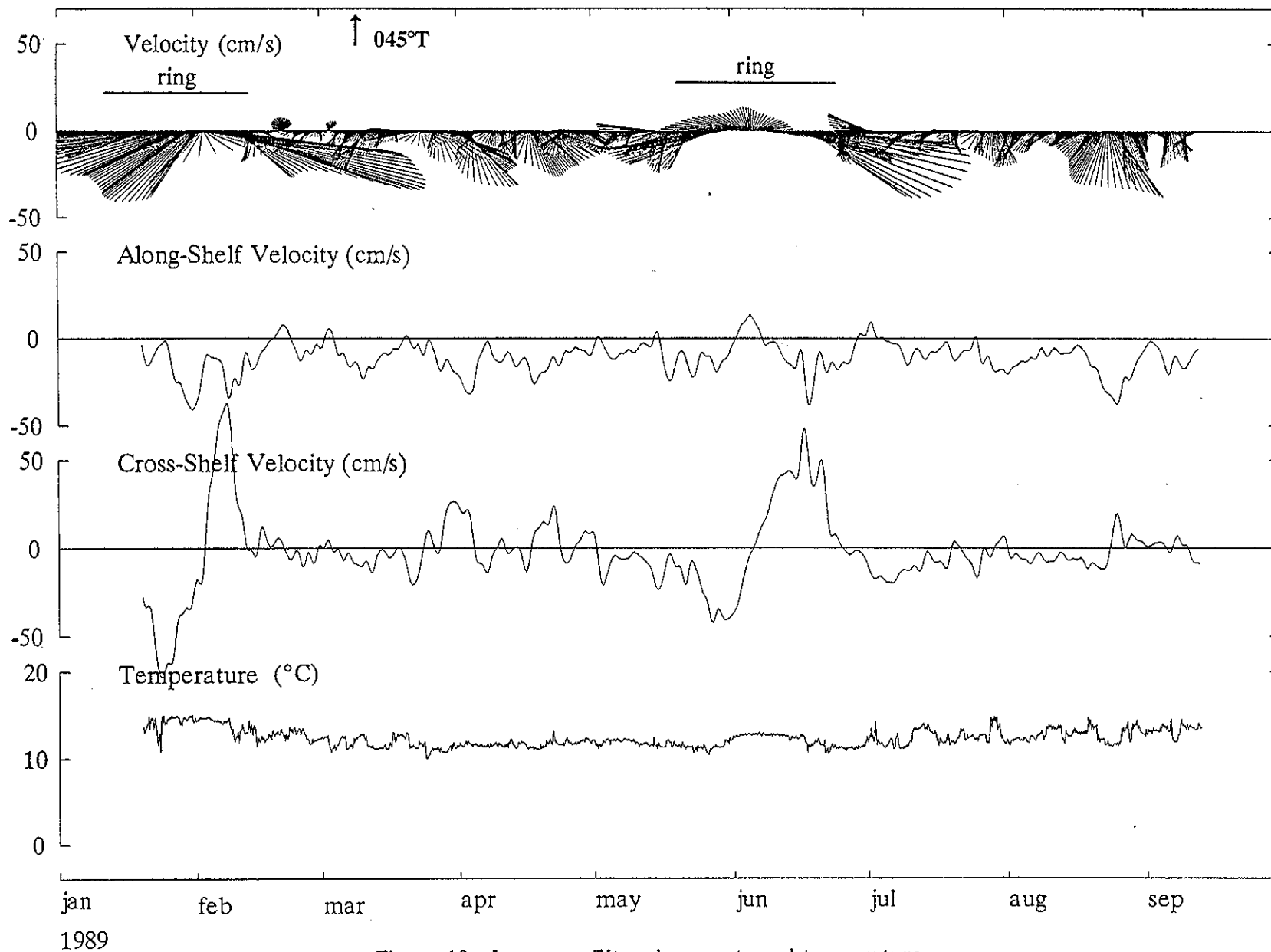


Figure 10. Low-pass-filtered currents and temperature.  
 (b) Deployment A at 100 m depth. January through September 1989.

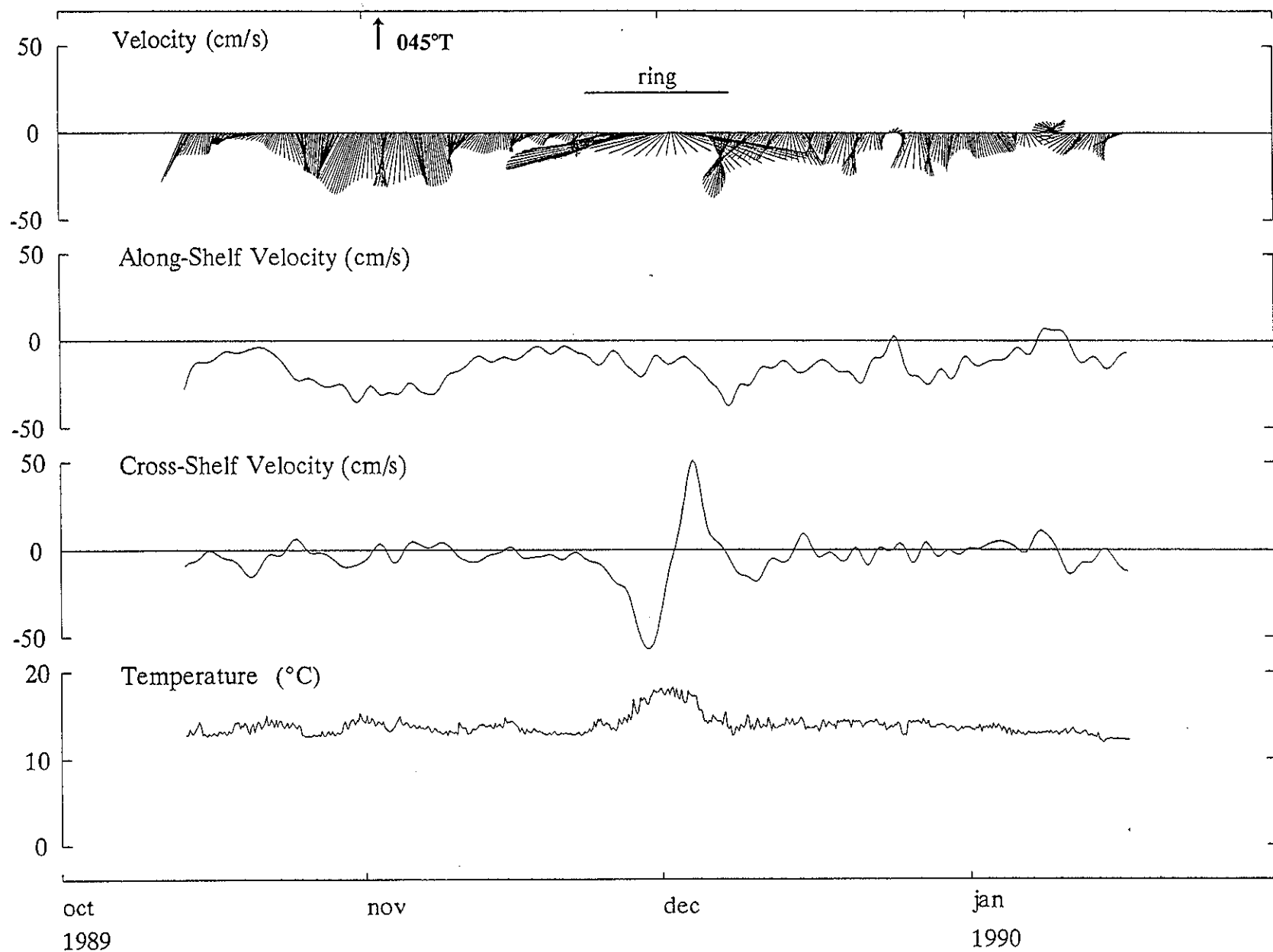


Figure 10. Low-pass-filtered currents and temperature.  
 (c) Deployment B at 100 m depth. October 1989 through January 1990.

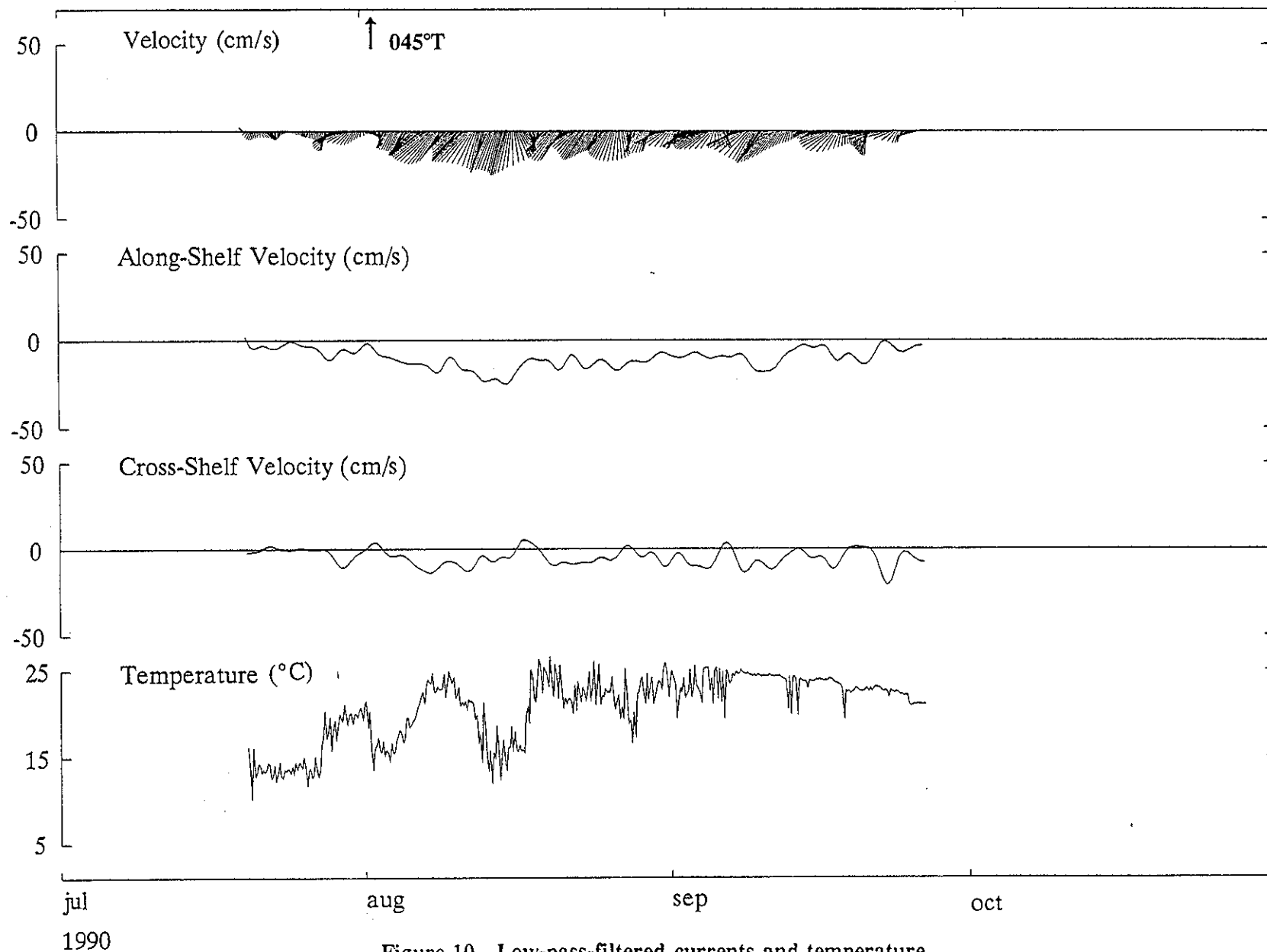


Figure 10. Low-pass-filtered currents and temperature.  
 (d) Deployment D at 25 m depth. July through October 1990.

near-surface current is evident flowing southwestward, parallel to the regional depth contours. During deployments B and D [Figures 10(c) and (d)], the low-frequency current rarely shows any northeastward transition. The strongest flows are associated with three warm-core ring (WCR) events evident in the record in January, May/June, and November/December 1989 [Figures 10(a)-(c)]. These features exhibit strong flows and sharp changes in direction over short periods of time. Significant warming is visible in the temperature record during these events, confirming the presence of WCRs. Note also, that most of the WCR energy was restricted to the cross-shelf component of the flow, indicating that the ring centers passed close to the mooring site as they translated to the southwest.

Figures 11(a) and (b) present vector plots of the current velocity and temperature for the 21-month period considered here. The vectors are plotted every 8 h. The seasonal character of the temperature record at 25 m is seen in these Figures. Seasonal warming of the surface mixed-layer during the summer months is visible in the 25-m temperature record whereas the temperature at 100 m (below the seasonal pycnocline) is unaffected. The advection of warm water by WCRs can be seen in the 100-m temperature record.

A vector plot showing wind velocity and current at 25-m depth for the duration of the meteorological/wave package deployment (deployments C and D) is given in Figure 12. Unfortunately, the current meter at 25 m failed during deployment C so only about 2½ months of concurrent wind and current data are available from deployment D. As with the current, the wind data have been smoothed using a 50-h low-passed filter. The lack of coherence between the wind and the near-surface current is evident in this Figure.

## 4.2 STATISTICAL SUMMARIES

Monthly mean values were calculated for the current velocity in the rotated coordinate system. The results are summarized in Figure 13 for the 21-month period of this analysis. The monthly mean along-shelf velocity at the 106-Mile Site was about 10 cm/s to the southwest for the entire measurement period at both 25- and 100-m depth. The cross-shelf monthly mean shows considerable variability primarily due to the passage of WCRs. The southwestward mean observed is consistent with the hypotheses for the regional circulation in the Slope Sea discussed earlier.

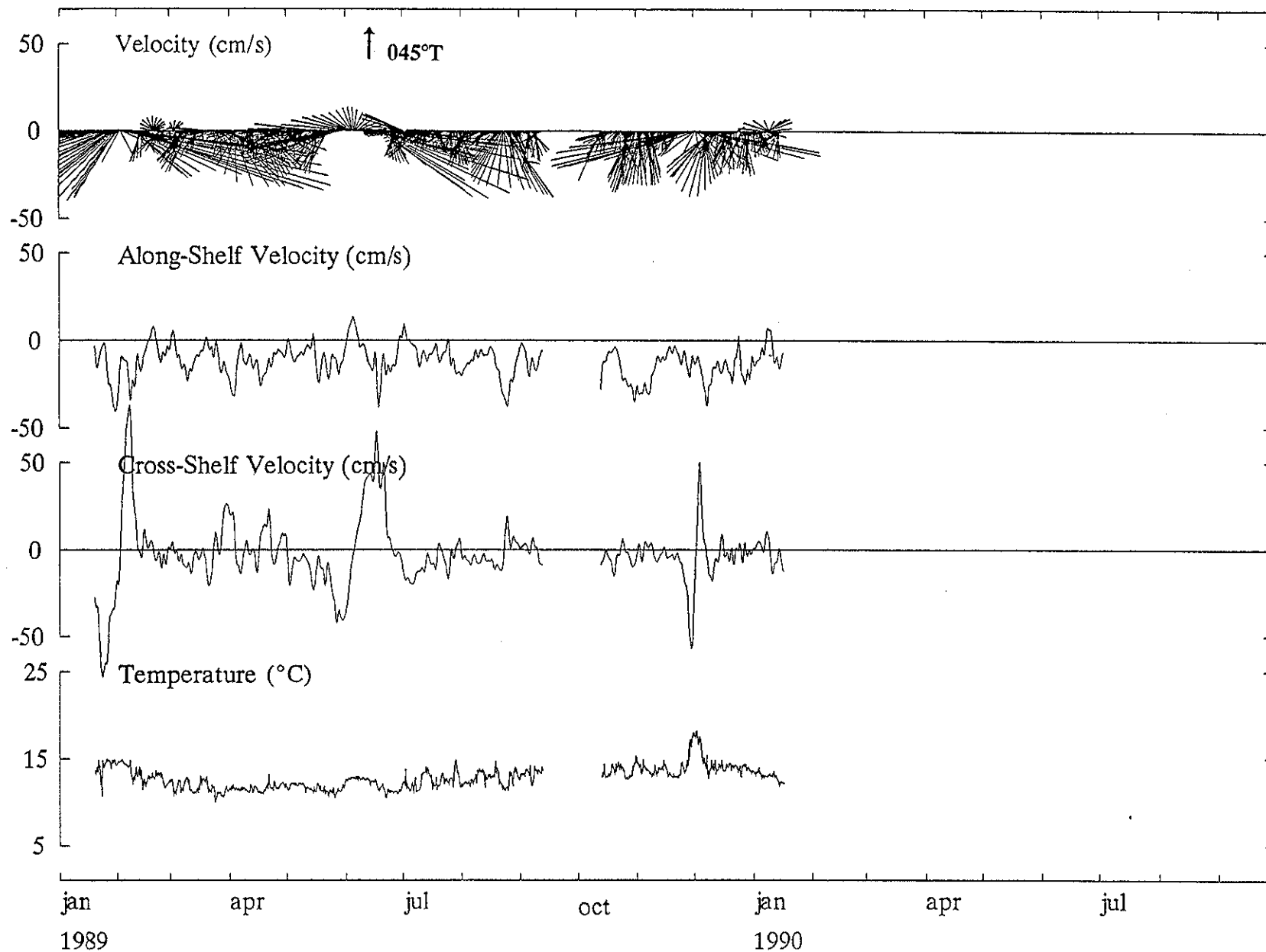


Figure 11. Low-pass-filtered currents and temperature.  
 (b) Entire deployment at 100 m depth. Through September 1990.

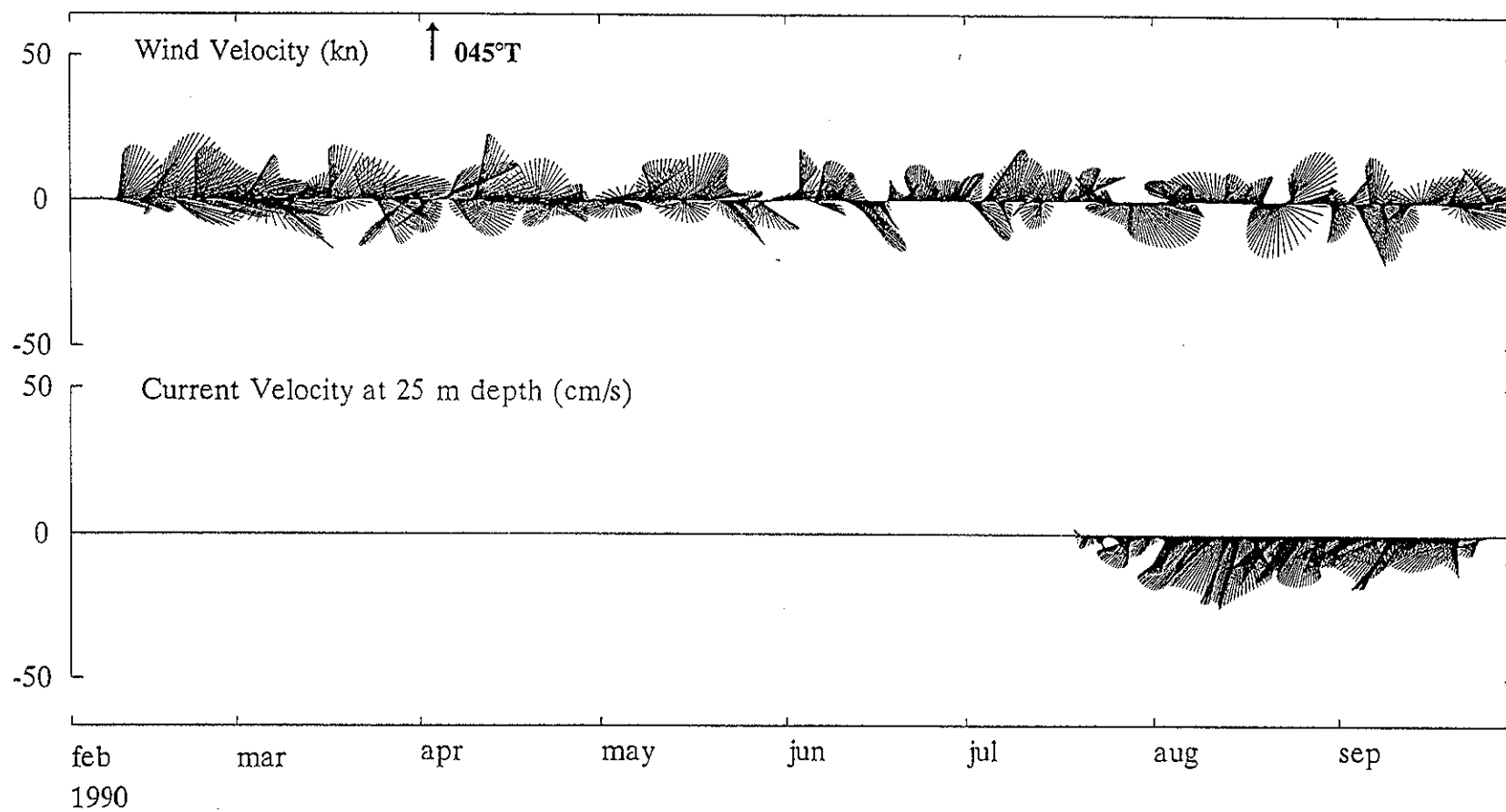


Figure 12. Low-pass-filtered wind and current.  
Deployments C and D. February through September 1990.

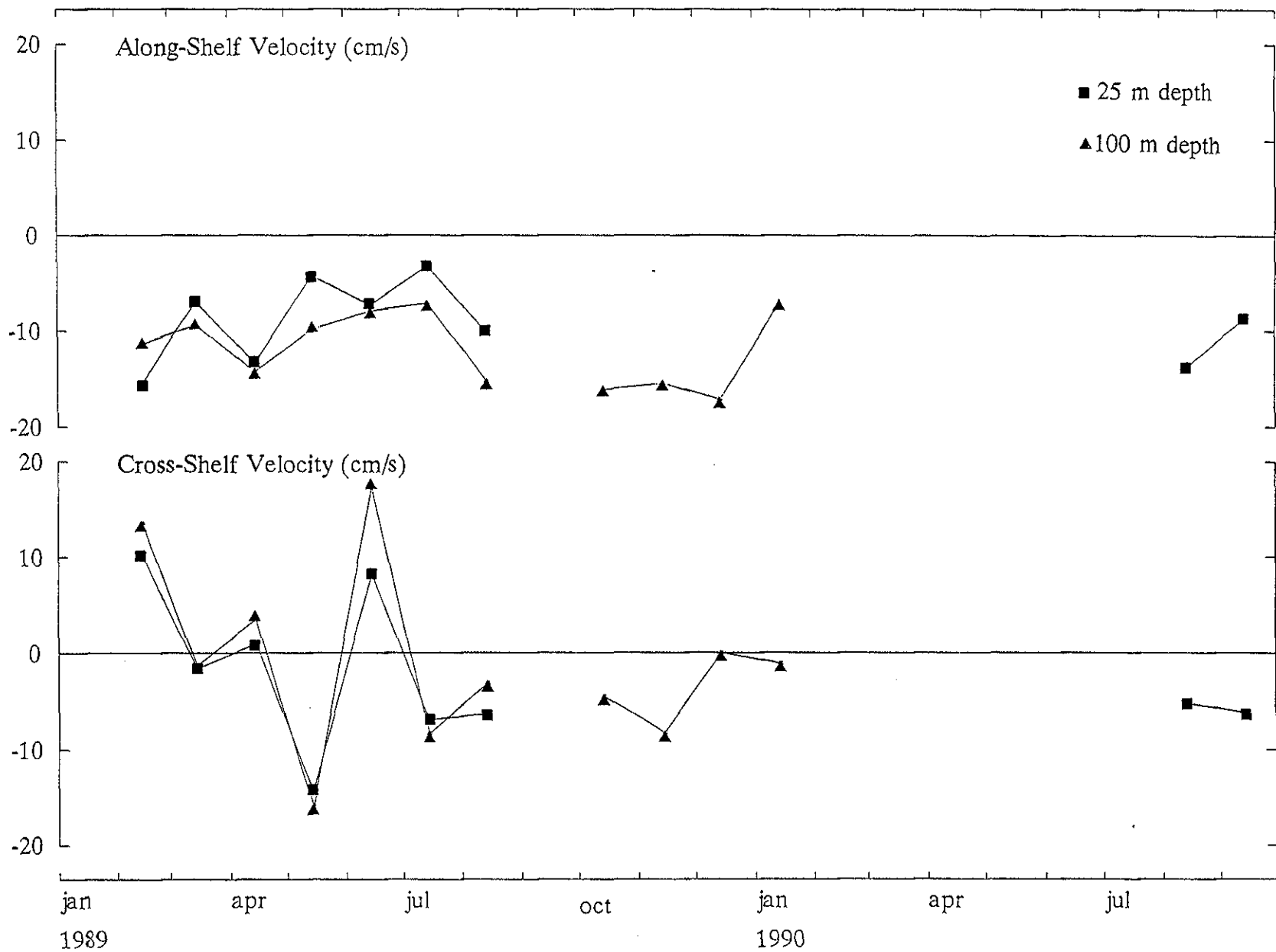


Figure 13. Monthly mean along- and cross-shelf velocities.  
All deployments.

Scatter plots of the hourly current velocities are presented on the lefthand side of Figures 14(a)-(c). Scatter plots are created by plotting a single point for each hourly velocity observation. Each point marks the tip of a velocity vector whose length is proportional to the current speed and whose direction indicates the direction of the flow. These Figures are oriented in a north and east coordinate system and *not* in the along- and cross-shelf coordinate system used for the previous stick plots. The shape and density of the cloud of points indicate the frequency of the flow at any speed and direction.

On the righthand side of Figures 14(a)-(c) are the principal component axes and the mean velocity vectors of the corresponding current records, represented by arrows and crosses, respectively. The principal component axes are the principal axes of variation in the current velocity. The long axis indicates the direction in which most of the speed variation occurs. The short axis is chosen perpendicular to this. The length of the either axis is equal to the variance of the velocity in that direction. Currents that are evenly distributed in all directions would result in principal component axes of equal length.

The current velocity at both depths during deployment A show a definite elongation of the velocity variance in the cross-shelf direction, whereas during deployments B and D the scatter is evenly distributed in all directions. This apparent inconsistency is caused by the presence of strong cross-shelf flows associated with passing WCRs during deployment A. (The single ring event of deployment B was weaker, more brief, and had a smaller statistical effect, causing little elongation of the principal axes although it is visible in the scatter diagram.) The resulting statistical picture of the low-frequency flow field is that of a background flow with a southwestward mean (at approximately 10 cm/s) and a uniform velocity variance in all directions ( $\pm 15$  cm/s standard deviation), which is periodically superposed by strong (approximately 60 cm/s) cross-shelf flows associated with ring events.

Joint probability distributions of current speed and direction for both hourly and low-passed data are presented in tabular and graphical form in the Appendix to this report.

#### 4.3 FREQUENCY ANALYSIS

A time-series of current velocity can be statistically represented by a combination of oscillations of different amplitudes at different frequencies. Some processes that generate currents, such as winds and tides, are associated with specific frequency bands (or periods). This frequency-domain analysis has the

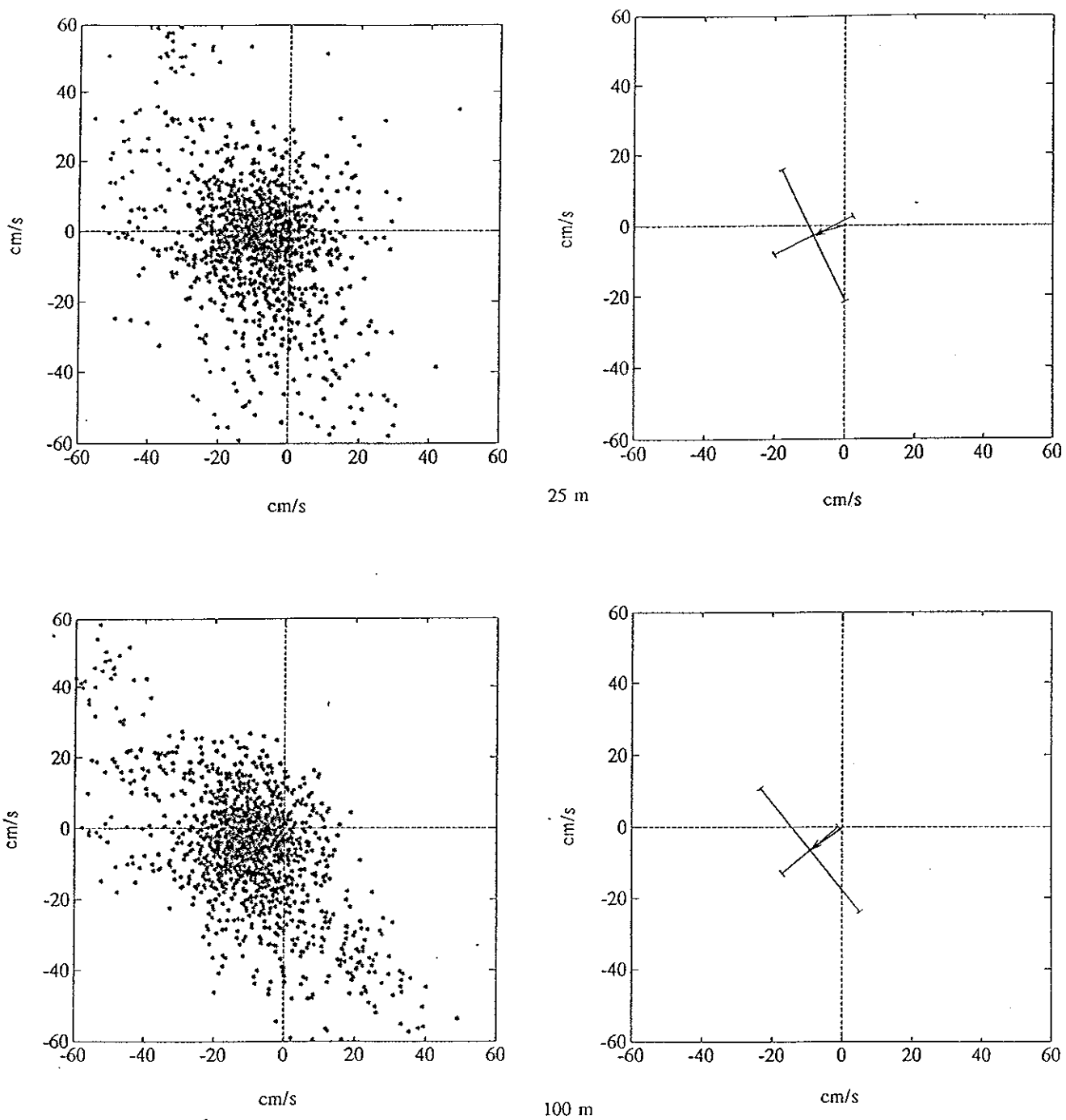


Figure 14. Scatter plot, principal component axes, and mean for current velocity.  
 (a) Deployment A. January through September 1989.

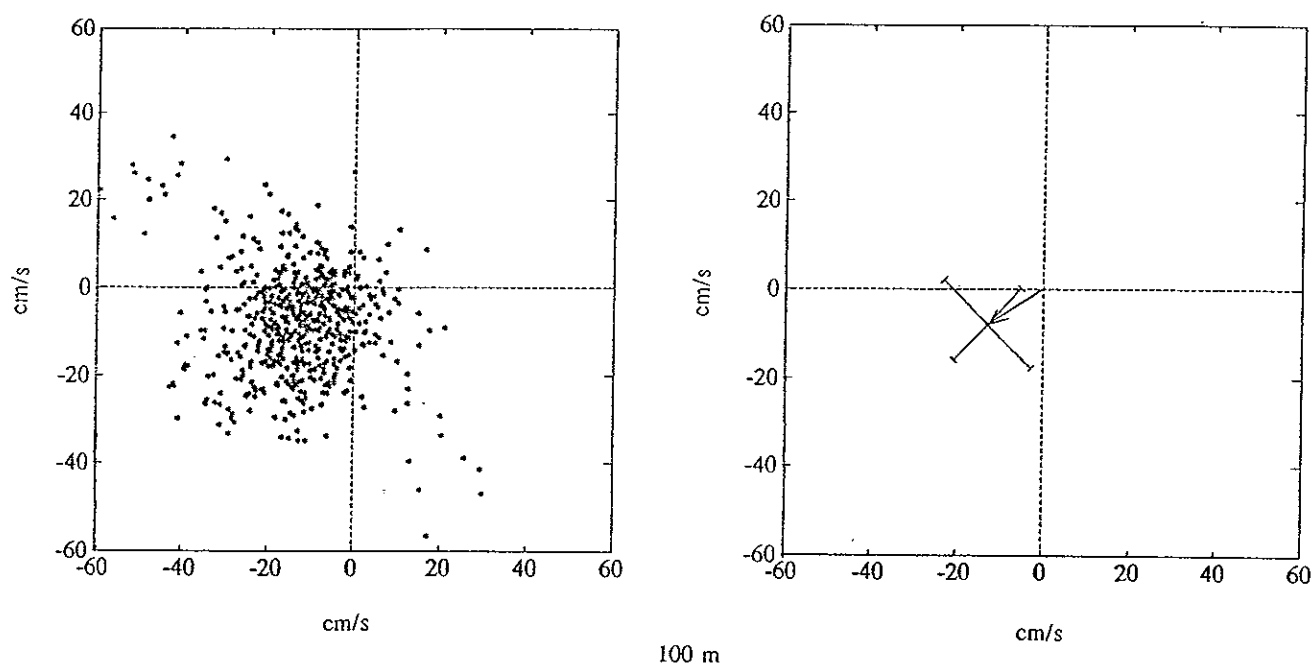


Figure 14. Scatter plot, principal component axes, and mean for current velocity.  
(b) Deployment B. October 1989 through January 1990.

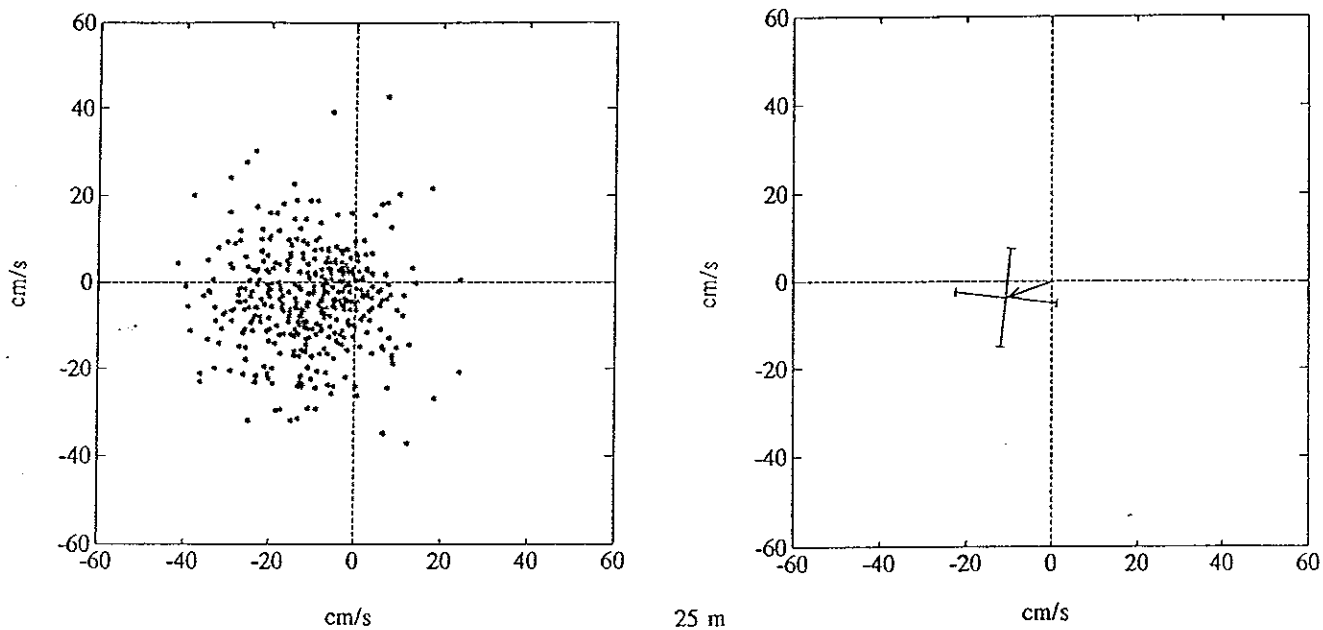


Figure 14. Scatter plot, principal component axes, and mean for current velocity.  
(c) Deployment D. July through October 1990.

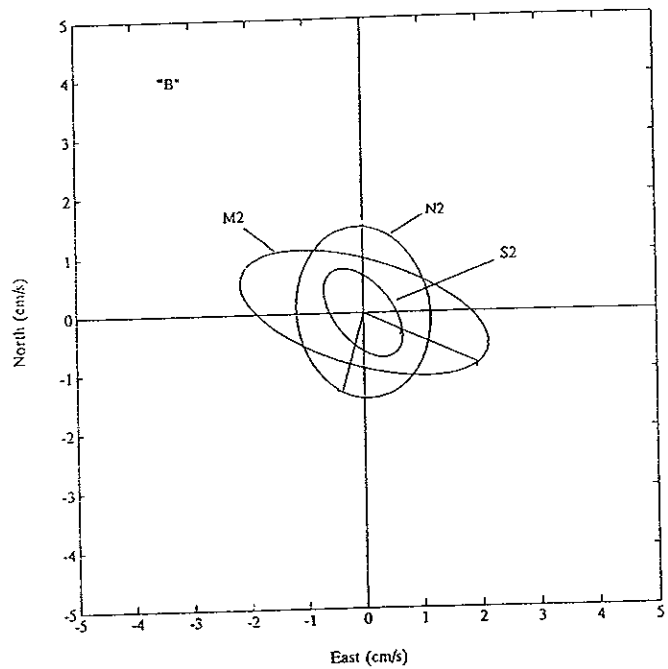
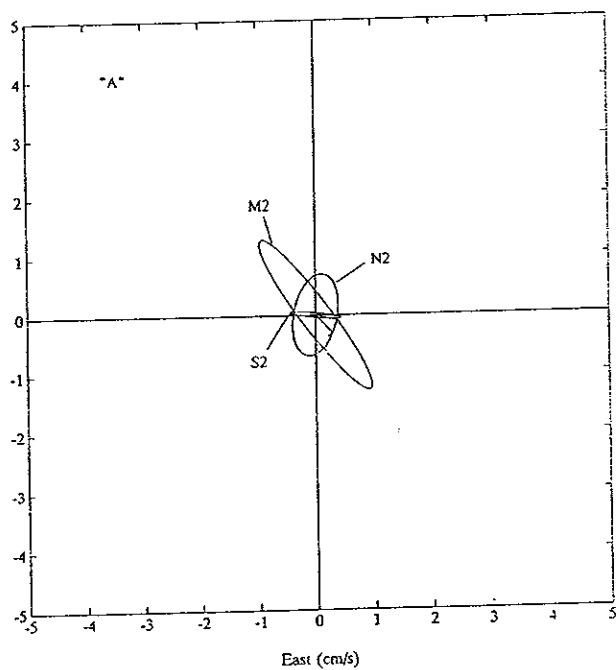
advantage of revealing the influence of these processes by the presence or absence of current oscillations at those frequency bands. Tidal harmonic analysis and spectral analysis of the current records are presented here.

Tidal harmonic analysis is the processes of fitting oscillations at the tidal frequencies to the current data. Since the tides are driven by the gravitational forces of the sun and moon, tidal frequencies (or periods) are known very precisely from astronomical observations. The calculation results in a list of amplitudes and phases for each tidal frequency. This analysis was performed on the hourly current velocity using a program developed by the Canadian Government (see Foreman, 1978) that uses a least-squares technique.

The results of the harmonic tidal analysis performed on the current-velocity time-series for the primary tidal constituents are summarized in Figures 15(a) and (b) where the computed tidal ellipses are shown. The complete listing of all tidal constituents is given in the Appendix. (A number of short gaps in the VMCM current data record during deployment A made harmonic tidal analysis impossible due to the sensitivity of the analysis to time base errors.) The tidal current vector at any phase of the tide is determined by drawing an arrow from the center of the ellipse to a point on the ellipse. The ellipses are plotted relative to geographical north, not the along-shelf coordinate system used previously. The point on the ellipse that corresponds to the velocity vector position at 0000 h Greenwich Mean Time (GMT) is shown as a radial line that intersects the ellipse.

The magnitude of tidal amplitudes for all of the constituents is quite small ( $< 4$  cm/s), as is expected in the open ocean of the Slope Sea. The semidiurnal constituents M2 (12.42-h period), S2 (12.00-h period), and N2 (12.66-h period) exhibit the most energy, but their magnitudes is small as compared to the long-period fluctuations. The ellipse of the largest component, M2, is oriented in the cross-shelf direction as expected.

To quantify the magnitude of current variability at all frequencies, the spectral energy density (autospectra) of the current velocity is computed. Autospectra provide an indication of the relative contribution to the total variance of the time series of oscillations at different frequencies. Figures 16(a)-(c) present the autospectra of the along- and cross-shelf components of the current velocity in an area-preserving plot. (In this form, the area under the curve between two frequencies is proportional to the energy, or variance, within that frequency band.) The mean has been removed from the current-velocity time-series before calculating the autospectra. The autospectra from the four time-series have

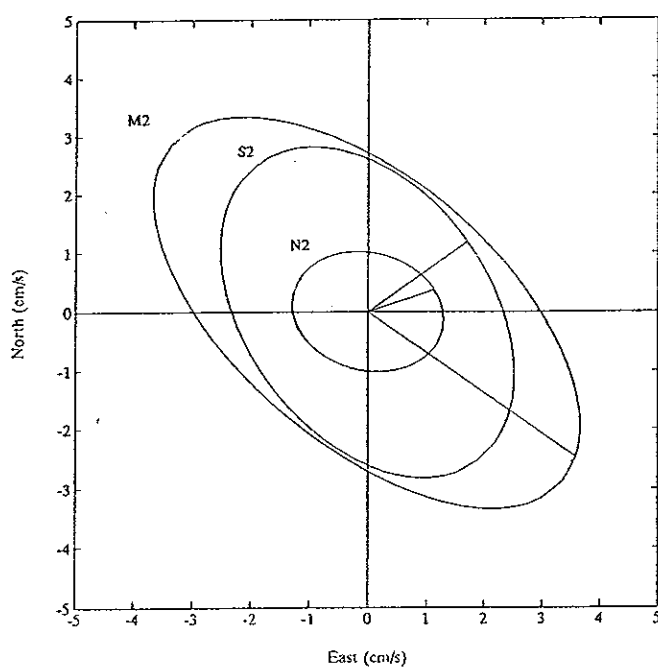


**Figure 15. Tidal ellipses of the major tidal constituents based on harmonic analysis of current velocity.**

M2: Lunar semidiurnal (12.42 h). S2: Solar semidiurnal (12.00 h).

N2: Lunar elliptic (12.66 h).

**(a) Deployments A and B at 100 m depth.**



**Figure 15. Tidal ellipses of the major tidal constituents based on harmonic analysis of current velocity.**

**M2: Lunar semidiurnal (12.42 h). S2: Solar semidiurnal (12.00 h).**

**N2: Lunar elliptic (12.66 h).**

**(b) Deployment D at 25 m depth.**

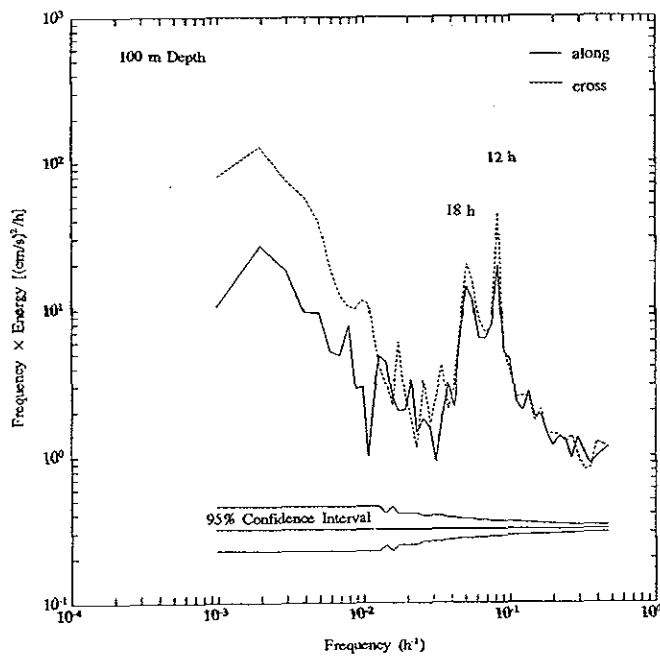
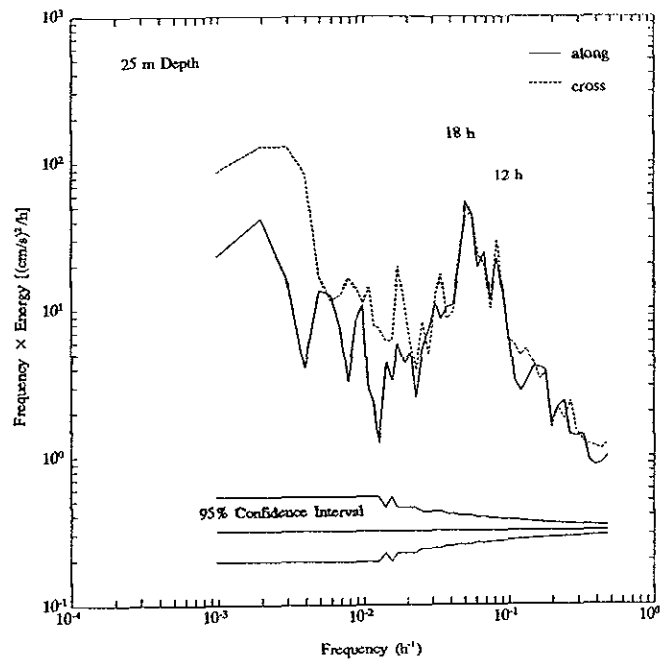


Figure 16. Energy spectra of the along- and cross-shelf components of current velocity.  
(a) Deployment A.

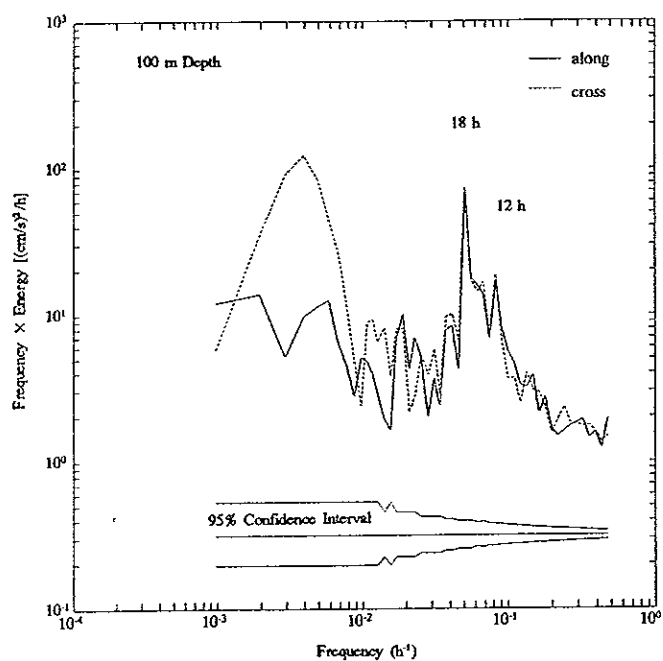


Figure 16. Energy spectra of the along- and cross-shelf components of current velocity.  
(b) Deployment B.

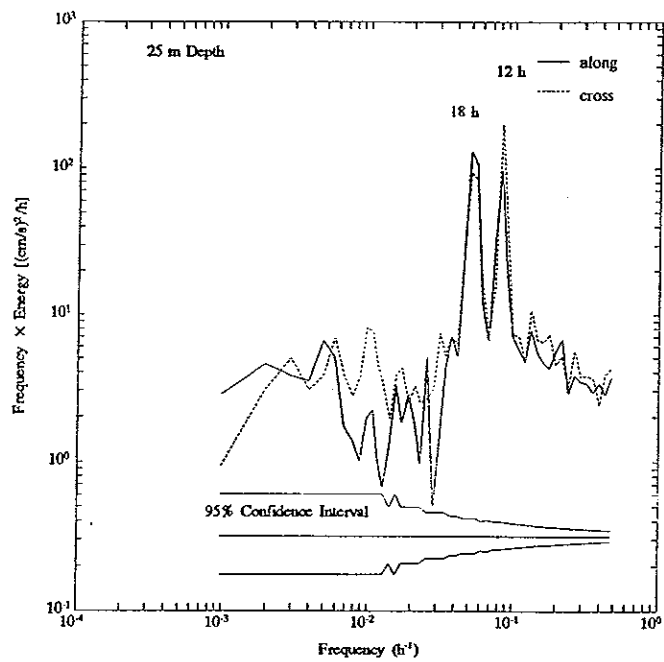


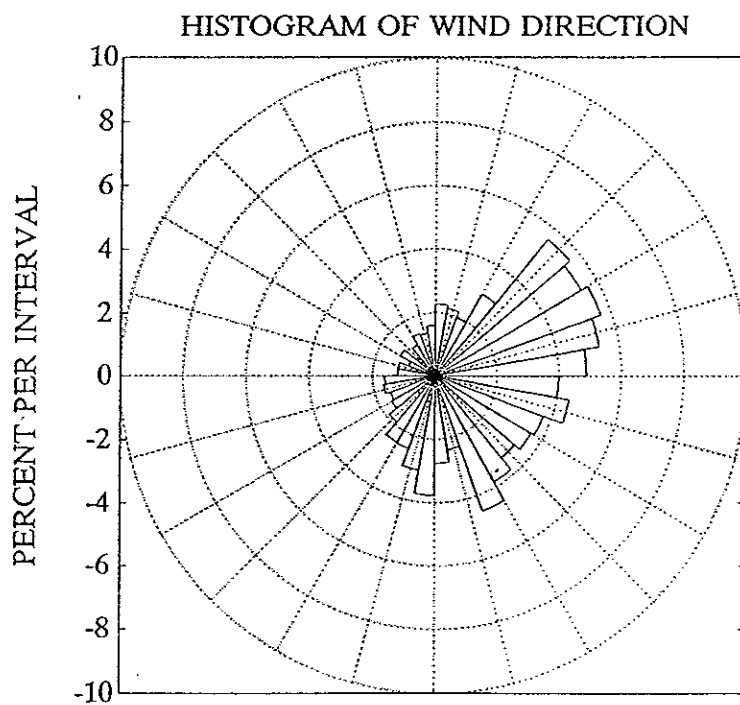
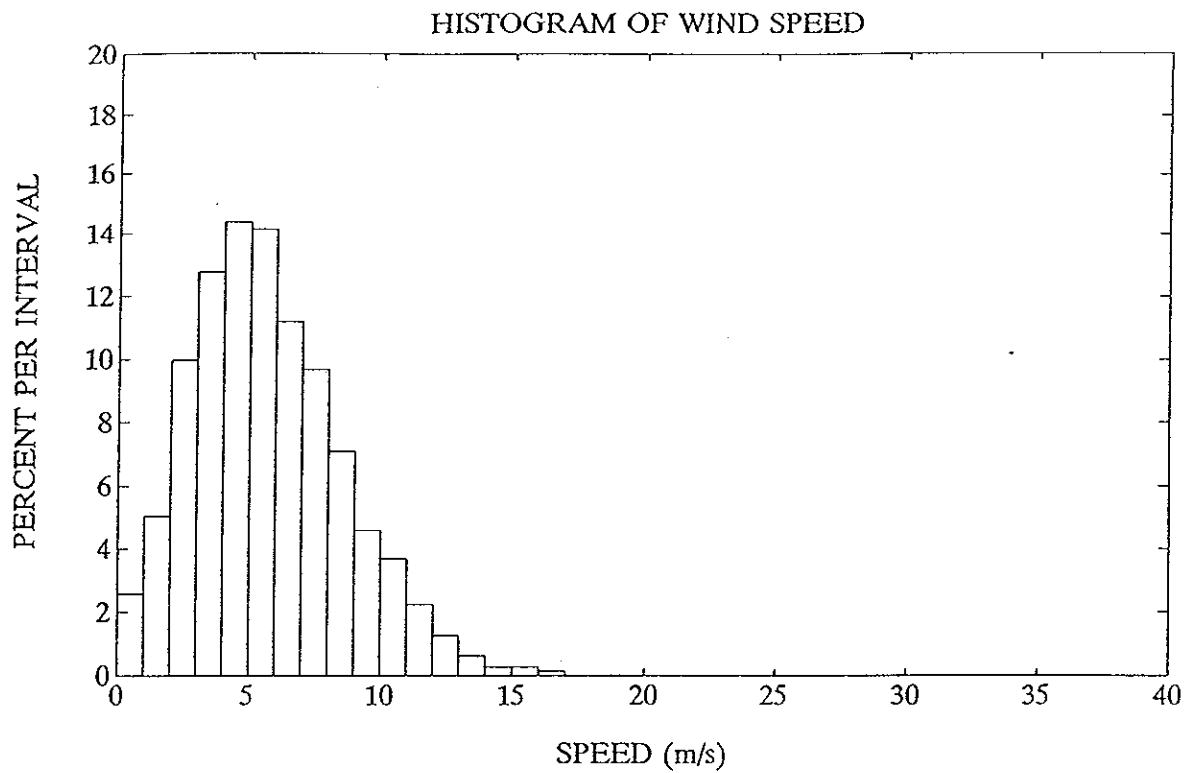
Figure 16. Energy spectra of the along- and cross-shelf components of current velocity.  
(c) Deployment D.

very similar characteristics. Narrow, distinct peaks appear at the semidiurnal tidal (12-h) and inertial (18-h) frequencies and have roughly the same energy in both the along- and cross-shelf directions. However, with the exception of deployment D, most of the energy is at low frequency, with periods of 4 days and longer, occurring primarily in the cross-shelf component. This is consistent with the occurrence of strong cross-shelf flows associated with WCRs in deployments A and B. Wind-driven current variability typically occurs at periods between 1.5 to 8 or 10 days because winds are most effective at forcing changes in currents in this band. Energy between 1.5 to 4 or 5 days in deployments A and B and between 1.5 and longer in deployment D is conspicuously absent. This indicates that the local winds have little effect on the currents, assuming that the energy present above 5 days is associated with WCRs. The lack of coherence between the wind and current seen in the time-series plots of deployment D tends to confirm this.

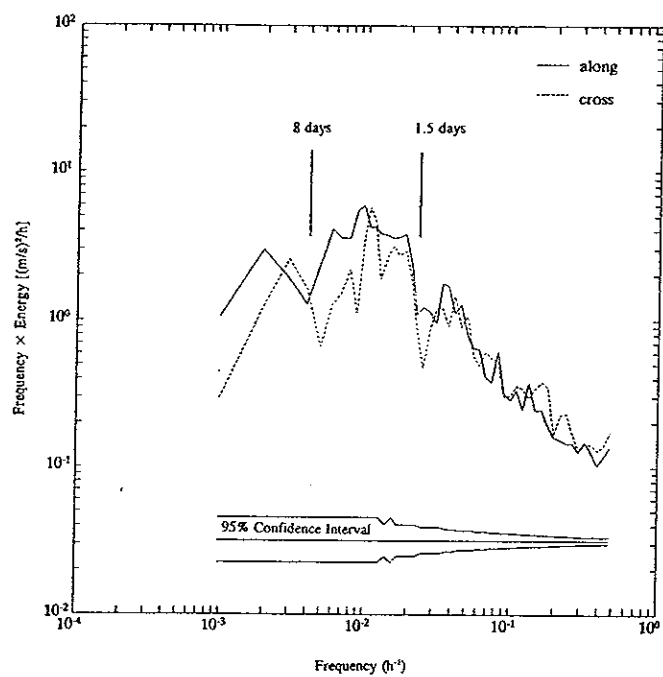
#### 4.4 WIND AND WAVE ANALYSIS

Figure 17 is a statistical summary of the wind speed and direction for the period of deployment of the meteorological/wave package (deployments C and D). A table of bivariate statistics of wind speed and direction is presented in the Appendix. Wind velocity was measured at a height of 4.3 m above the sea surface. The oceanographic convention is used here for wind direction; direction indicates the direction *toward* which the wind flows. Figure 17 uses the geographic coordinate system with North being up and East to the right. The mean wind speed was about 5 m/s, with only about 1% of the hourly measurements above 15 m/s, and the direction was predominantly between northeastward and southeastward with the most frequent direction toward the northeast.

The autospectrum of the wind is presented in Figure 18. The wind velocity has been rotated into along- and cross-shelf components for consistency with the current-velocity spectra, but along- and cross-shelf have no particular meaning for the wind (which is demonstrated by the likeness of their spectra). What stands out in this Figure is a broad peak between about 1.5 and 8 days, with its maximum at 4 days where the variability of the wind is at its greatest. This means the meteorological time scale in the vicinity of the 106-Mile Site is about 4 days, or, put another way, the weather at the 106-Mile Site changes on average every 4 days.



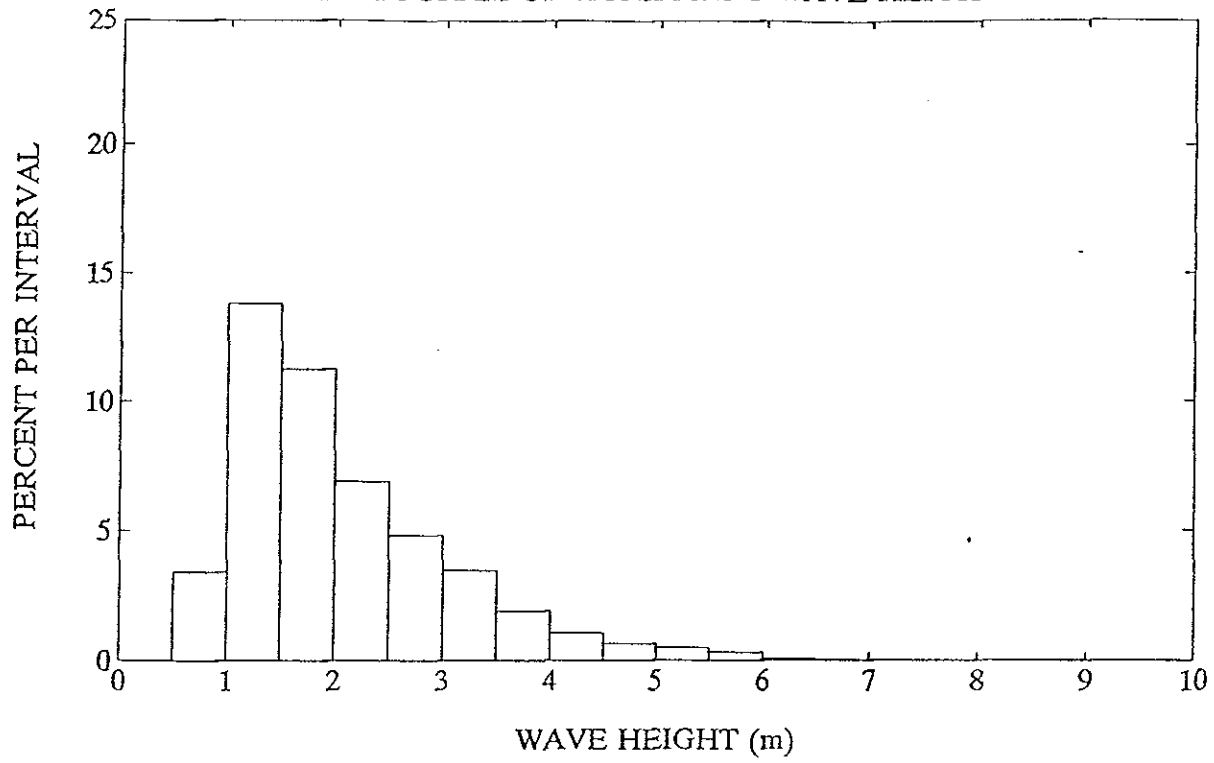
**Figure 17. Wind speed and direction for deployments C and D.**



**Figure 18. Energy Spectra of the along- and cross-shelf components of wind velocity for deployments C and D.**

Waves were measured using an accelerometer located inside the instrument well of the surface buoy. Period is measured directly, but height must be calculated from the second integral of the acceleration. Short-period waves ( $< 4$  s) are attenuated due to the large mass of the buoy and were logged as hourly average height and period equal to zero. Thus, the statistics of the longer period waves are unaffected, and in terms of surface-layer mixing, wave accelerations on the current meters, and mechanical wear of the mooring, longer period waves are of primary interest. Figure 19 and Tables 2 and 3 present statistical summaries of the wave data. Those hourly records where the wave period was short (and the period and height were recorded as zero) are not shown in the histograms but are given in the tables. Figure 19 indicates that for waves longer than 4 s the modal wave had an 8- to 10-s period and was 1-2 m high. Table 2 shows that waves greater than 3 m were observed about 8% of the time and that the largest waves observed were 6-7 m high. Table 3 shows that wave heights were correlated with wind speeds, especially for large wave heights. For example, 6-7 m waves occurred at wind speeds of 14-18 m/s.

HISTOGRAM OF SIGNIFICANT WAVE HEIGHT



HISTOGRAM OF WAVE PERIOD

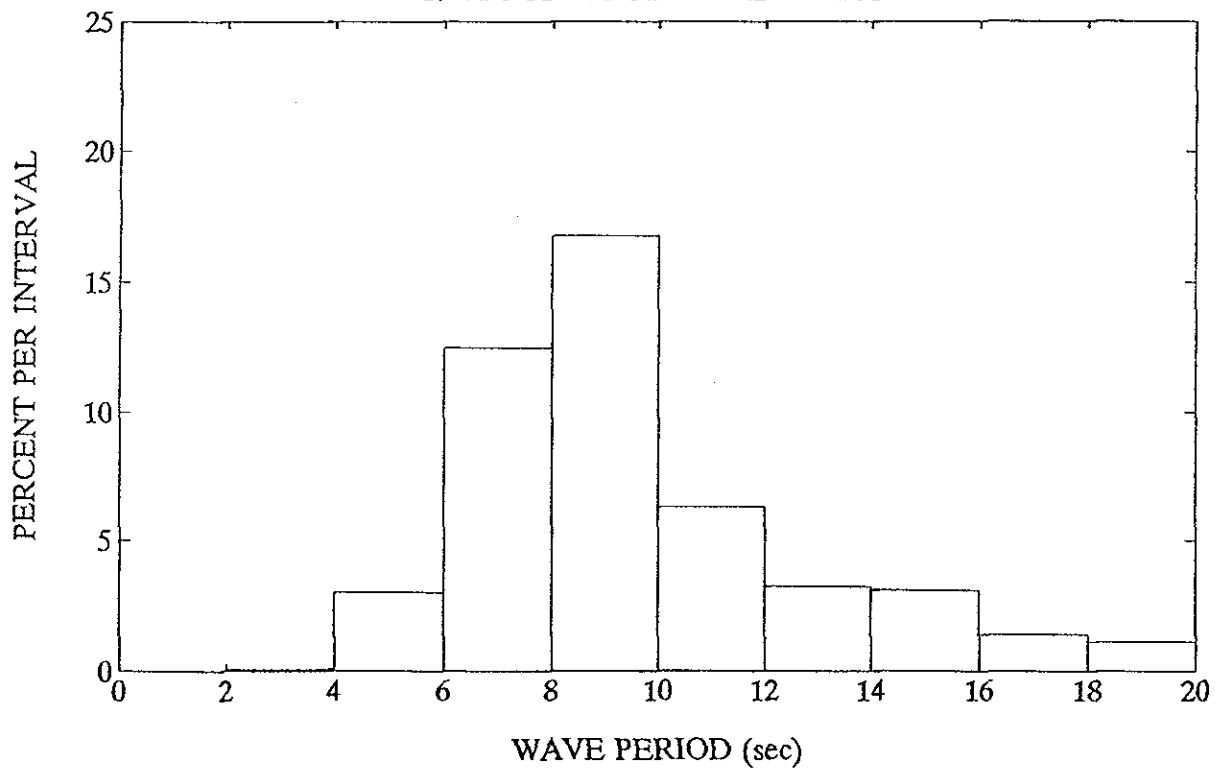


Figure 19. Significant wave height and period for deployments C and D.

Table 2. Bivariate statistics of hourly wave height and wave period for deployments C and D.

STATION: 106-Mile Site Real-Time Moorin											WATER DEPTH: 2600.0										
FILENAME: metc											FROM: 02/06/90 TO: 09/27/90			5579 DATA POINTS							
											WAVE HEIGHT (M)										
											0	1	2	3	4	5	6	7	8	9	
PERIOD		1	2	3	4	5	6	7	8	9	10										
(SEC)																					
0- 2	2	2898	0	0	1	0	0	0	0	0	0	SUM	2899	PRCT	52.2	CUM PRCT	100.0				
2- 4	4	0	1	2	0	0	0	0	0	0	0		3	0.1	47.8						
4- 6	6	24	97	44	1	0	0	0	0	0	0		166	3.0	47.7						
6- 8	8	23	314	256	90	10	0	0	0	0	0		693	12.5	44.8						
8- 10	10	47	451	214	144	49	20	5	0	0	0		930	16.7	32.3						
10- 12	12	41	172	44	38	32	23	0	0	0	0		350	6.3	15.5						
12- 14	14	16	121	25	13	3	0	0	0	0	0		178	3.2	9.2						
14- 16	16	27	125	12	6	0	0	0	0	0	0		170	3.1	6.0						
16- 18	18	7	50	16	5	0	0	0	0	0	0		78	1.4	3.0						
18- 20	20	6	38	18	0	0	0	0	0	0	0		62	1.1	1.6						
20- 22	22	0	14	10	1	0	0	0	0	0	0		25	0.5	0.5						
SUM		3089	1383	641	299	94	43	5	0	0	0		5554								
PERCENT		55.6	24.9	11.5	5.4	1.7	0.8	0.1	0.0	0.0	0.0										
CUM PRCT		100.0	44.4	19.5	7.9	2.6	0.9	0.1	0.0	0.0	0.0										

Table 3. Bivariate statistics of hourly wave height and wind speed for deployments C and D.

STATION: 106-Mile Site Real-Time Moorin											WATER DEPTH: 2600.0						
FILENAME: metc											FROM: 02/06/90		TO: 09/27/90		5579 DATA POINTS		
														WAVE HEIGHT (M)			
		0	1	2	3	4	5	6	7	8	9						
WIND																	
SPEED		1	2	3	4	5	6	7	8	9	10						
(M/S)												SUM	PRCT	CUM PRCT			
0- 2	2	189	211	22	3	0	0	0	0	0	0	425	7.6	100.0			
2- 4	4	701	503	59	6	0	1	0	0	0	0	1270	22.8	92.4			
4- 6	6	1013	420	135	17	5	4	0	0	0	0	1594	28.6	69.6			
6- 8	8	749	182	186	28	8	12	0	0	0	0	1165	20.9	41.0			
8- 10	10	304	60	171	93	19	5	0	0	0	0	652	11.7	20.2			
10- 12	12	96	20	61	122	29	3	0	0	0	0	331	5.9	8.5			
12- 14	14	30	1	13	30	25	5	0	0	0	0	104	1.9	2.5			
14- 16	16	6	1	1	0	7	13	2	0	0	0	30	0.5	0.7			
16- 18	18	1	0	3	0	1	0	3	0	0	0	8	0.1	0.1			
18- 20	20	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0			
SUM		3089	1398	651	299	94	43	5	0	0	0	5579					
PERCENT		55.4	25.1	11.7	5.4	1.7	0.8	0.1	0.0	0.0	0.0						
CUM PRCT		100.0	44.6	19.6	7.9	2.5	0.9	0.1	0.0	0.0	0.0						

## 5.0 REFERENCES

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## **APPENDIX**

### **Bivariate Statistics and Tidal Analysis**

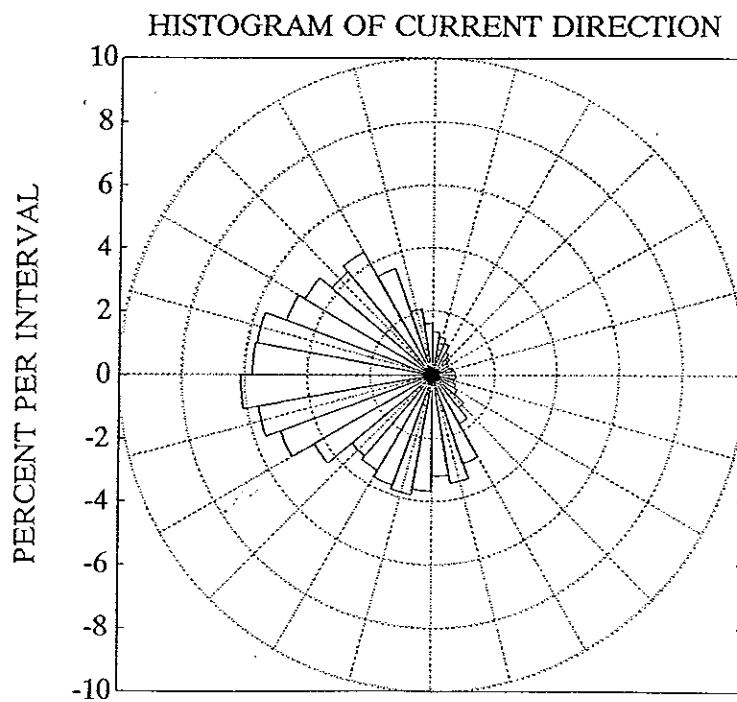
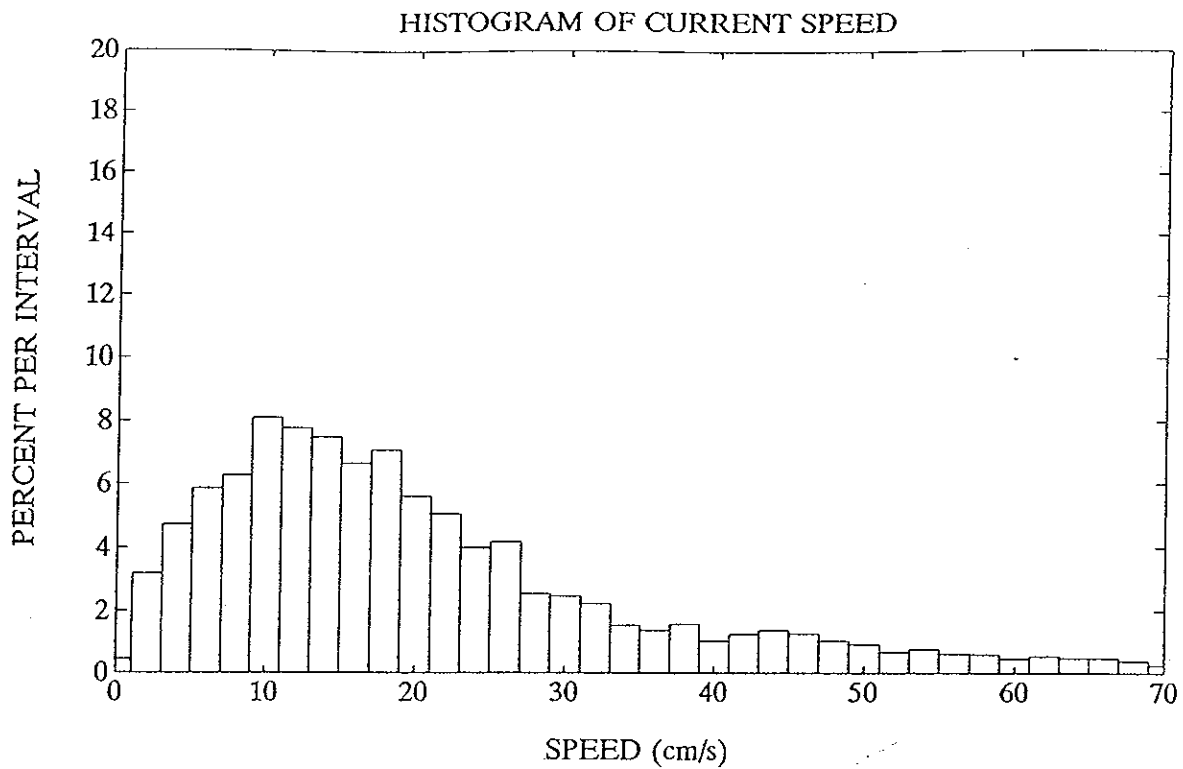


Figure A-1. Current speed and direction.  
(a) Deployment A at 25 m depth. January through September 1989.

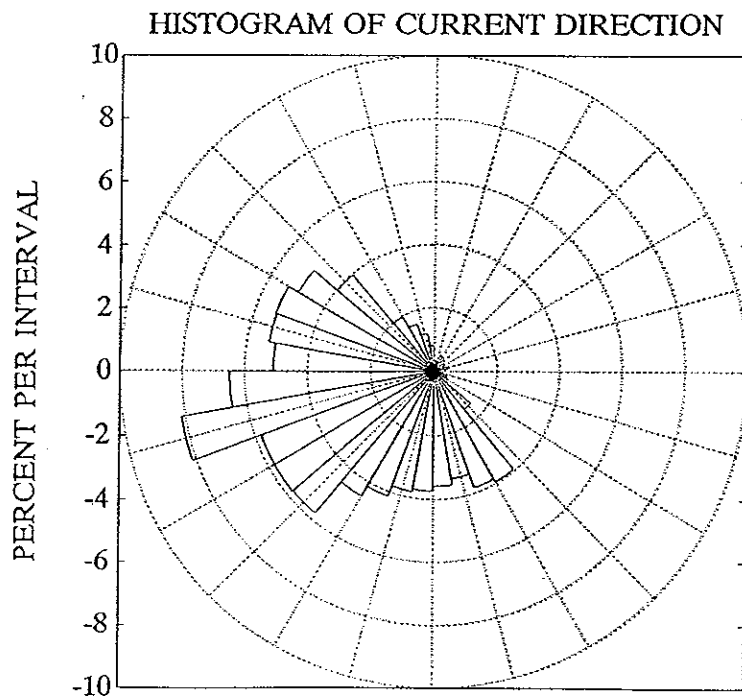
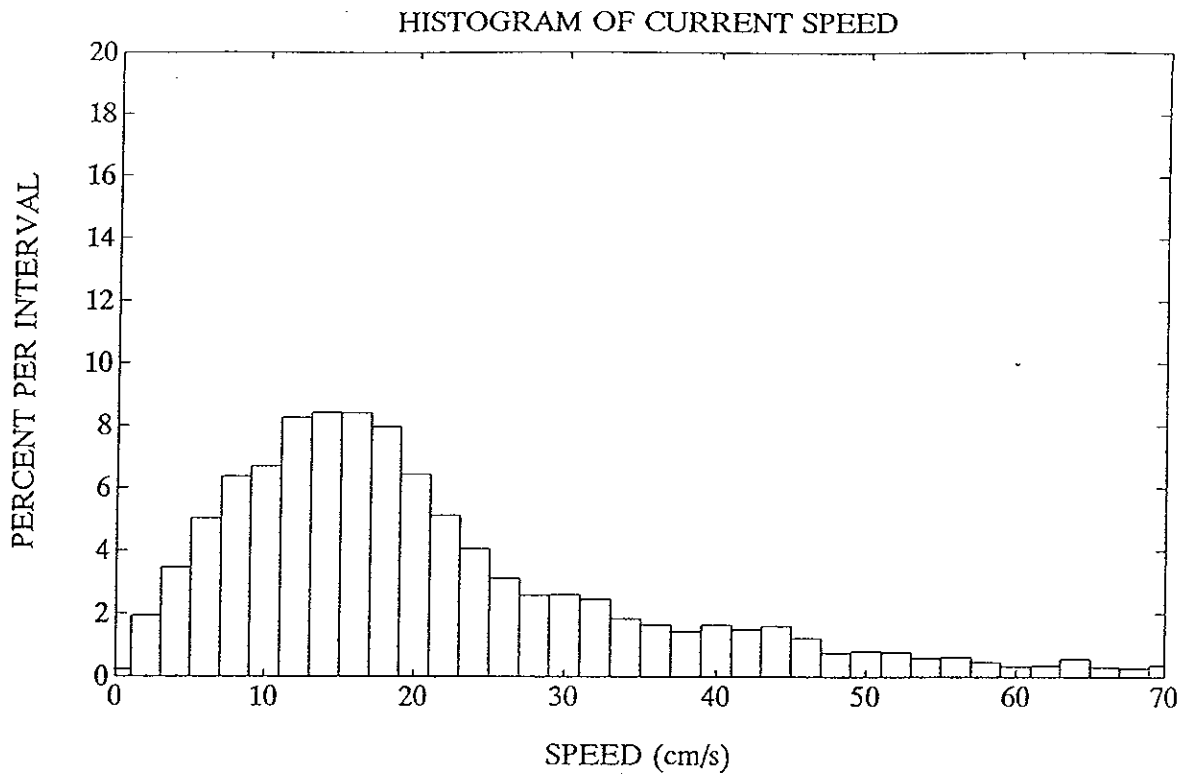
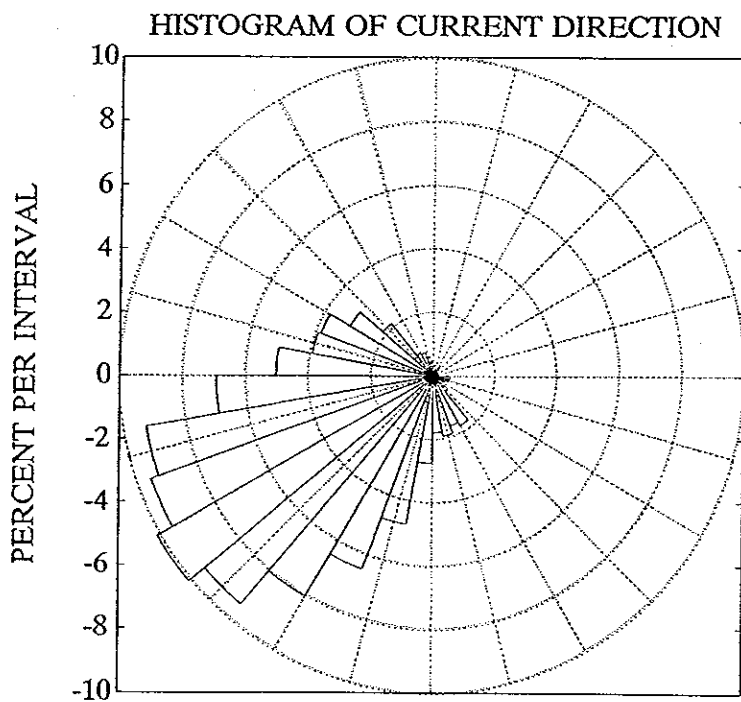
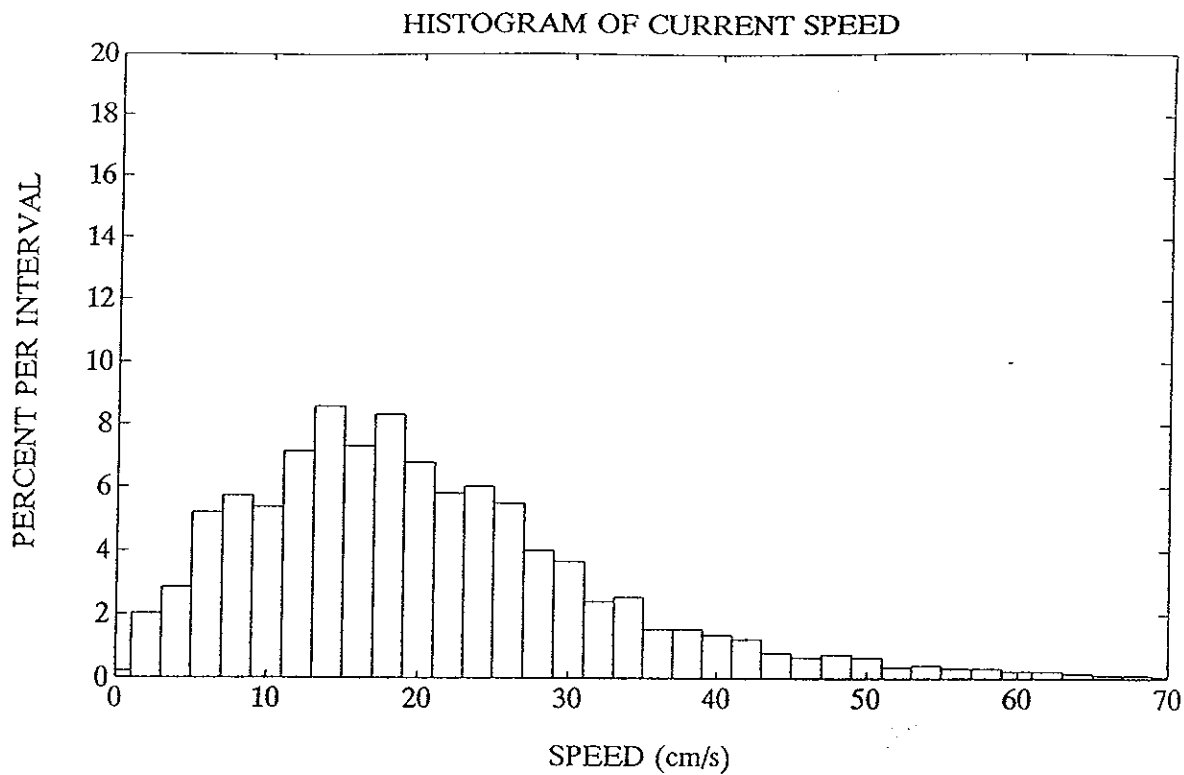
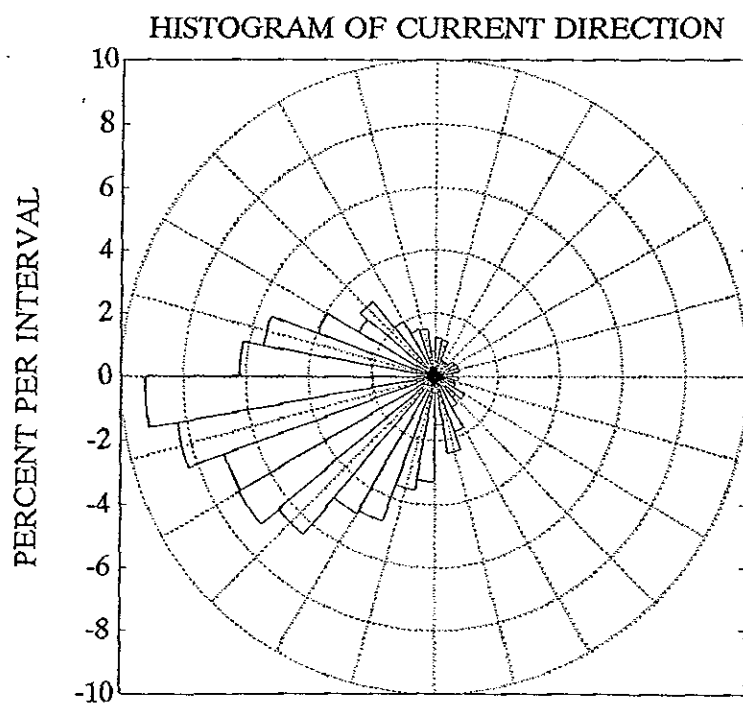
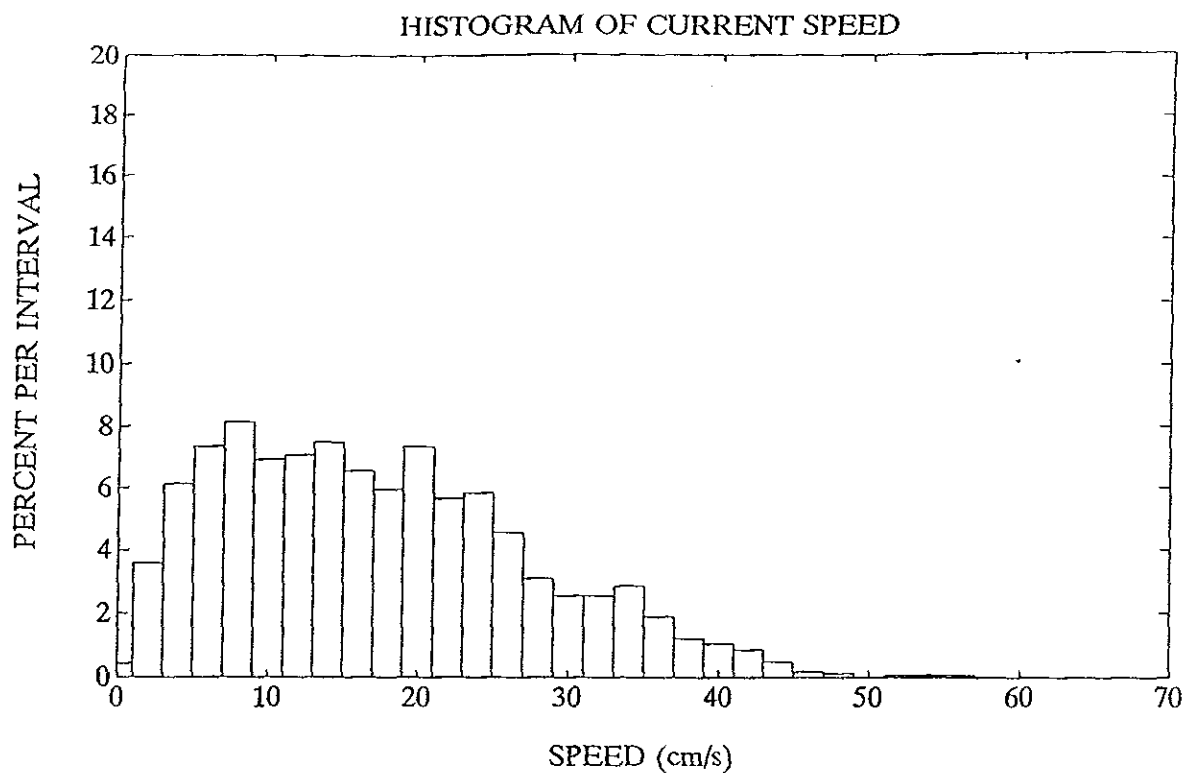


Figure A-1. Current speed and direction.  
(b) Deployment A at 100 m depth. January through September 1989.



**Figure A-1. Current speed and direction.**  
**(c) Deployment B at 100 m depth. October 1989 through January 1990.**



**Figure A-1. Current speed and direction.**  
**(d) Deployment D at 25 m depth. July through September 1990.**

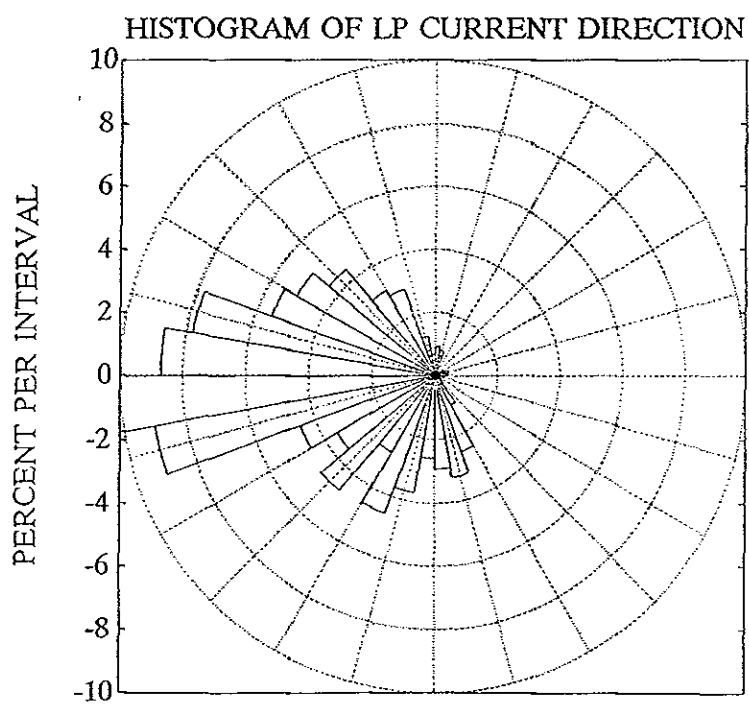
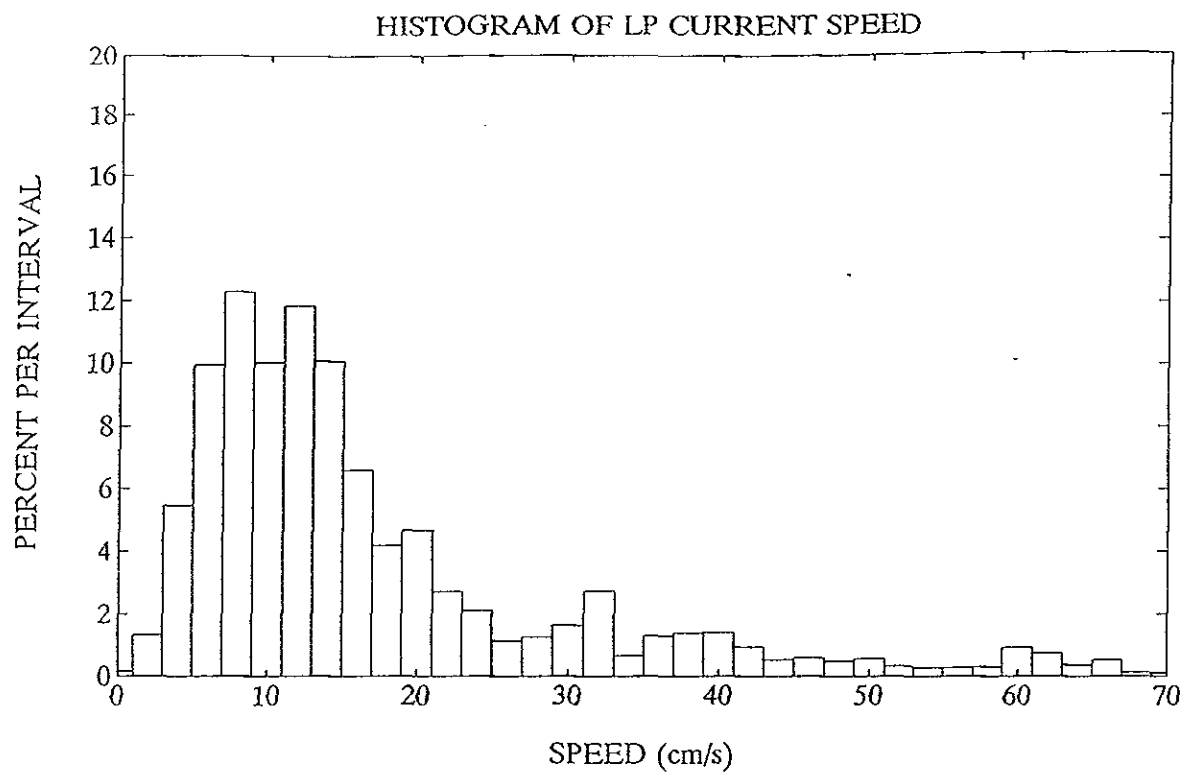


Figure A-2. Low-pass-filtered current speed and direction.  
(a) Deployment A at 25 m depth. January through September 1989.

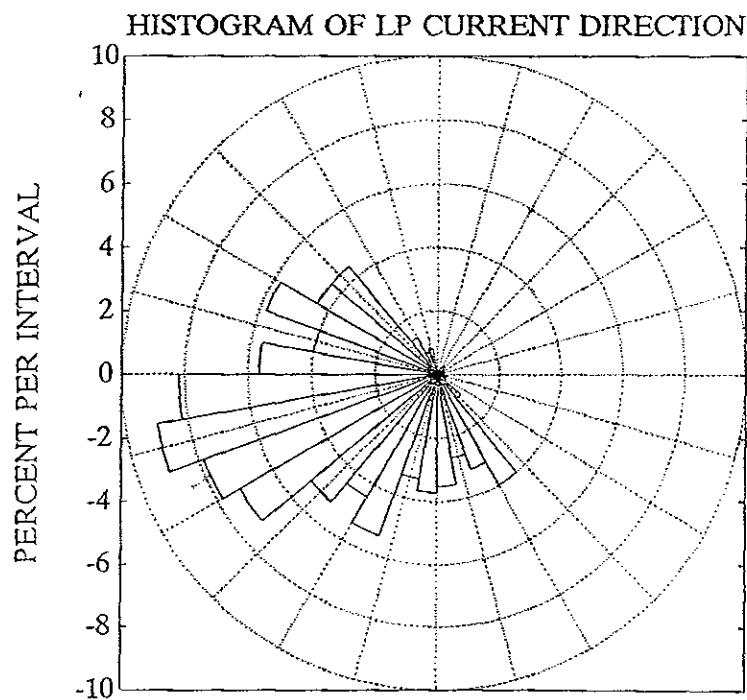
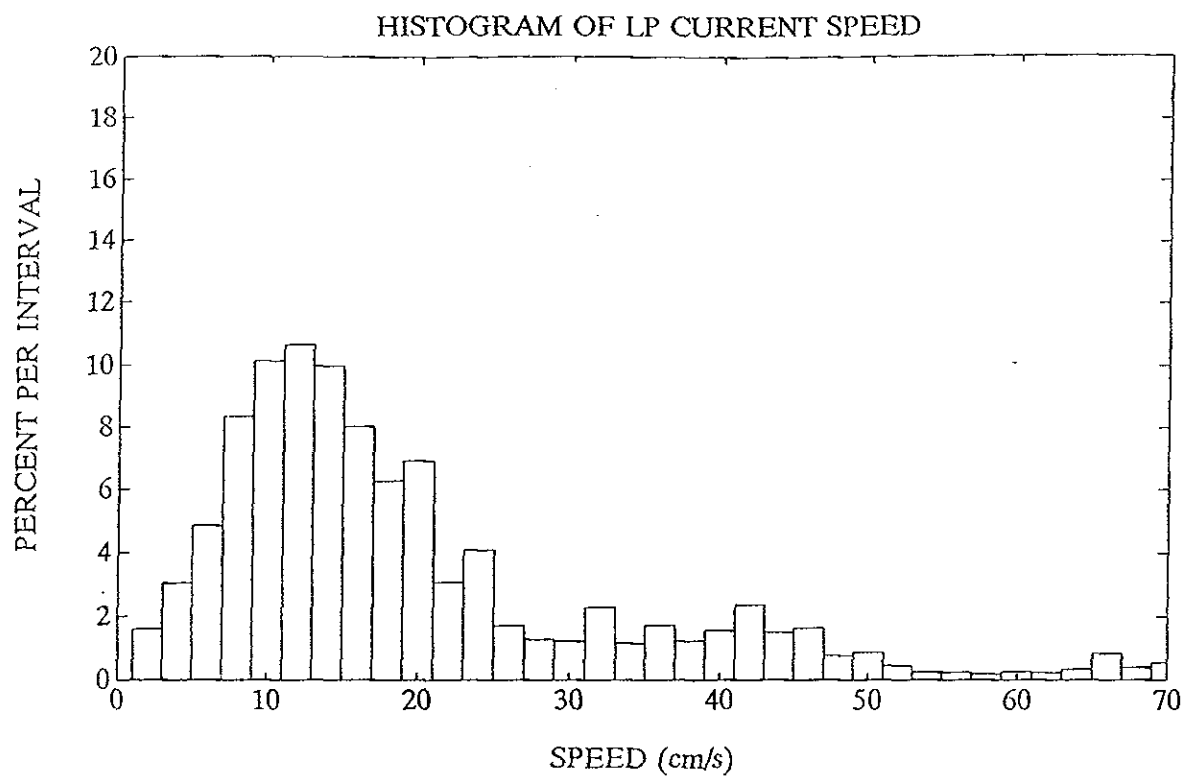
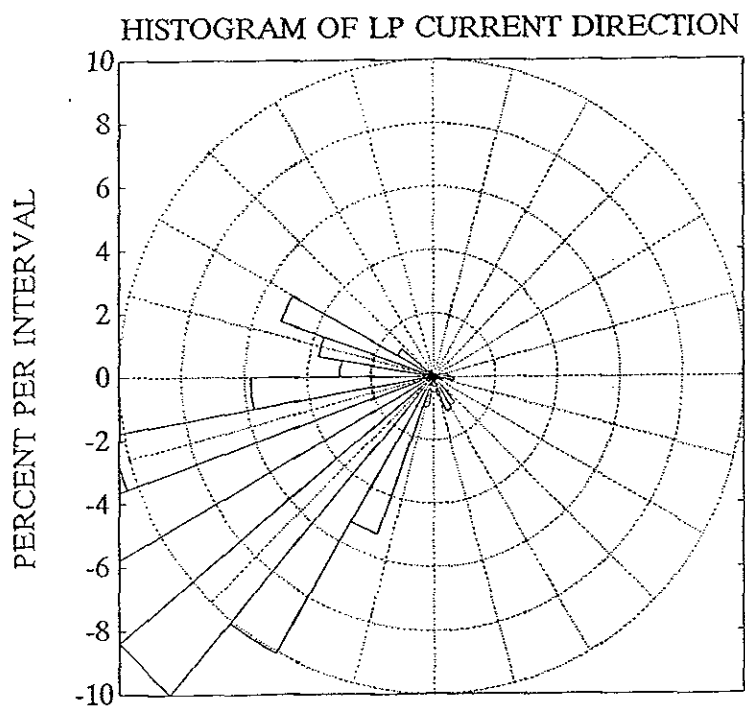
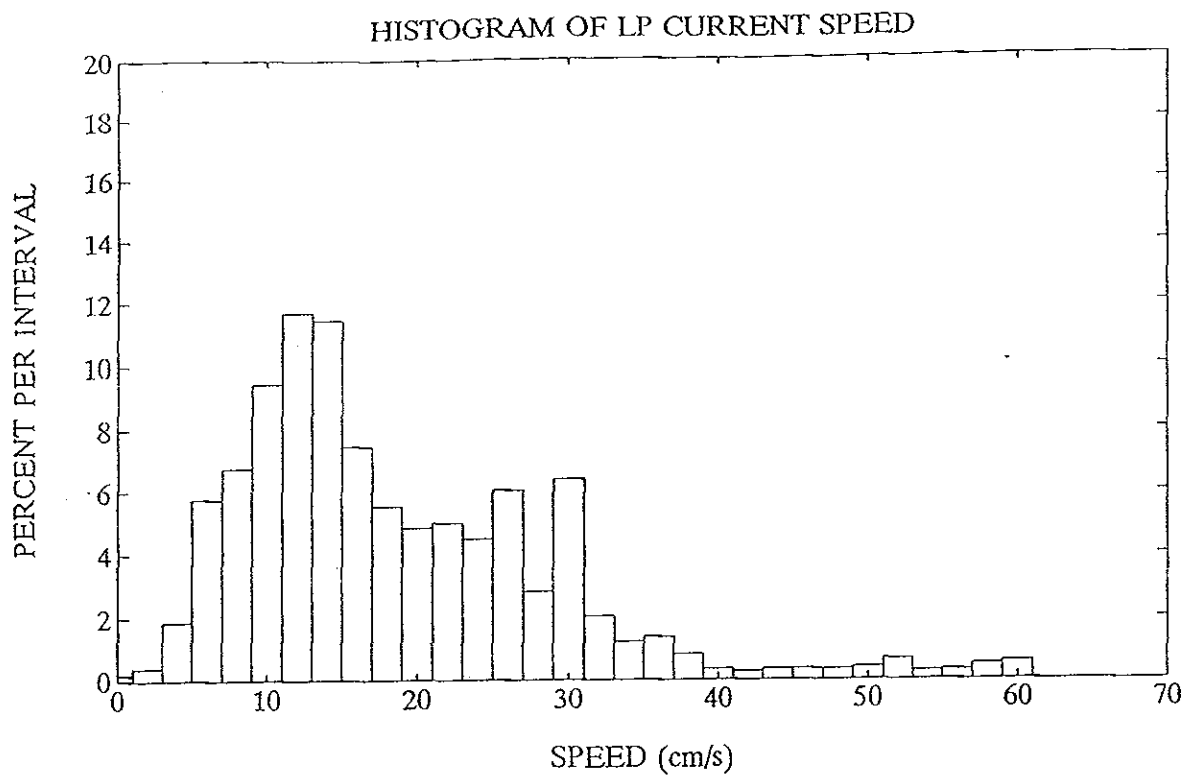
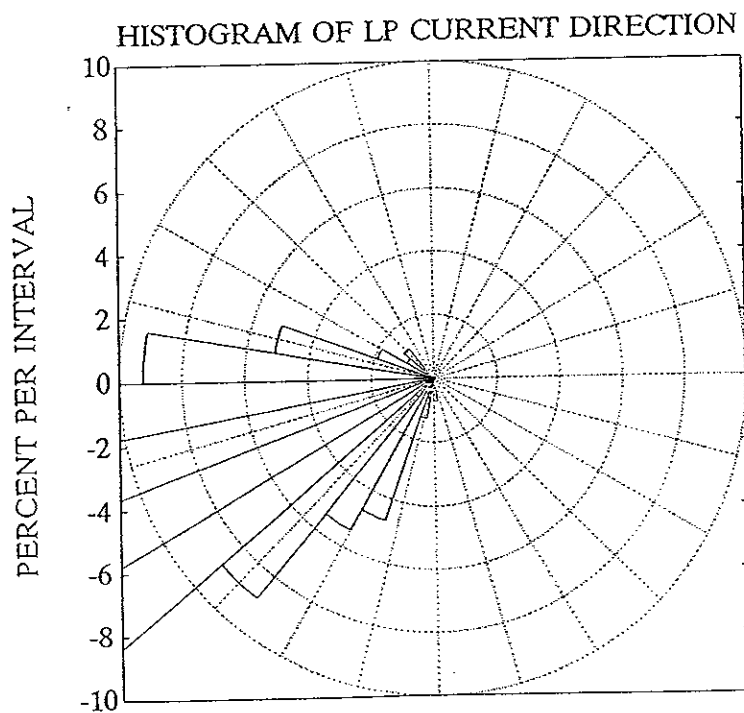
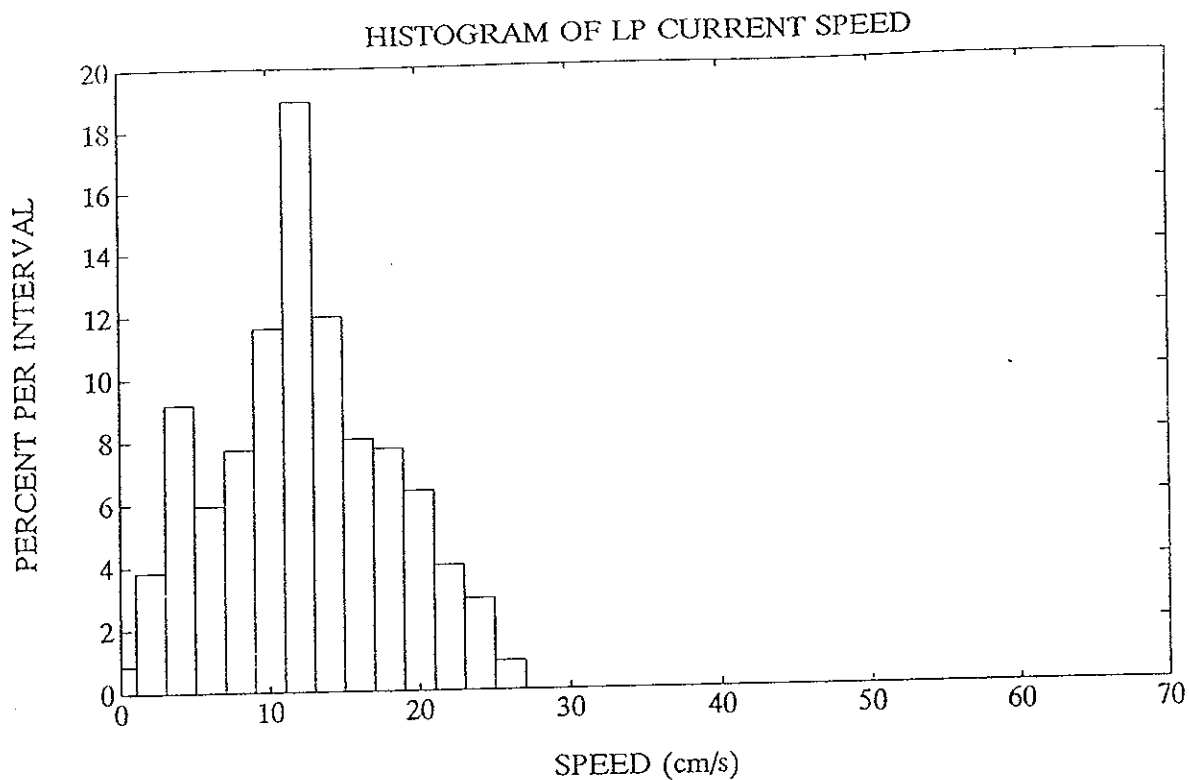


Figure A-2. Low-pass-filtered current speed and direction.  
(b) Deployment A at 100 m depth. January through September 1989.



**Figure A-2. Low-pass-filtered current speed and direction.**  
**(c) Deployment B at 100 m depth. October 1989 through January 1990.**



**Figure A-2. Low-pass-filtered current speed and direction.**  
**(d) Deployment D at 25 m depth. July through September 1990.**

Table A-1. Bivariate statistics of hourly currents.  
(a) Deployment A at 25 m depth.

# FREQUENCY DISTRIBUTION

STATION: 106-Mile Site Real-Time Moorin S/N: 372 INSTRUMENT DEPTH: 25.0 WATER DEPTH: 2600.0  
FILENAME: m6ma72 FROM: 01/20/89 TO: 09/13/89 5104 DATA POINTS

DIRECTION TOWARDS  
DEGREES

																					SUM	PERCENT
-0- 30	42	51	34	19	19	10	3	4	1	1	1	0	0	0	0	0	0	0	0	0	185	3.6
30- 60	22	31	21	6	11	6	5	1	3	0	1	1	0	0	0	0	0	0	0	0	108	2.1
60- 90	18	27	22	11	9	9	3	0	0	0	0	1	0	0	0	0	0	0	0	0	100	2.0
90-120	14	34	34	15	7	6	3	1	0	0	0	1	0	0	0	0	0	0	0	0	115	2.3
120-150	28	27	51	31	15	12	8	8	9	2	4	5	0	0	2	1	1	0	0	0	204	4.0
150-180	31	47	53	48	43	38	43	31	32	23	20	13	19	16	21	9	4	0	0	0	491	9.6
180-210	40	76	85	90	75	57	40	25	28	24	18	5	1	2	5	1	0	0	0	0	572	11.2
210-240	45	79	119	106	84	62	26	19	10	8	0	3	3	2	1	1	0	0	0	0	568	11.1
240-270	44	142	188	194	126	71	42	15	11	23	7	1	0	0	0	0	0	0	0	0	864	16.9
270-300	50	113	201	174	106	59	26	27	21	28	24	7	2	1	0	0	0	0	0	0	839	16.4
300-330	44	102	116	85	65	57	35	38	38	26	16	28	22	10	4	0	0	0	0	0	686	13.4
330-360	44	75	64	57	36	21	15	8	3	0	7	7	14	14	6	1	0	0	0	0	372	7.3
SPEED	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95		
CM/S																						
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100		
SUM	422	804	988	836	596	408	249	177	156	135	98	72	61	45	39	13	5	0	0	0	5104	
PERCENT	8.3	15.8	19.4	16.4	11.7	8.0	4.9	3.5	3.1	2.6	1.9	1.4	1.2	0.9	0.8	0.3	0.1	0.0	0.0	0.0		
CUM PRCT	100.0	91.7	76.0	56.6	40.2	28.6	20.6	15.7	12.2	9.2	6.5	4.6	3.2	2.0	1.1	0.4	0.1	0.0	0.0	0.0		

## SUMMARY STATISTICS

MEAN VELOCITY = 9.24 CM/S TOWARD 252 DEG T

MEAN EAST COMPONENT = -8.80 CM/S STANDARD DEVIATION = 14.37 CM/S

MEAN NORTH COMPONENT = -2.79 CM/S STANDARD DEVIATION = 19.44 CM/S

MEAN SPEED = 20.91 CM/S STANDARD DEVIATION = 15.25 CM/S

MAXIMUM = 53.41 CM/S

MAXIMUM = 70.64 CM/S

MAXIMUM = 83.65 CM/S

MINIMUM = -63.48 CM/S

MINIMUM = -77.01 CM/S

MINIMUM = 0.02 CM/S

IN A COORDINATE SYSTEM WHOSE Y AXIS IS DIRECTED TOWARD 45 DEGREES TRUE

MEAN X COMPONENT = -4.25 CM/S STANDARD DEVIATION = 19.98 CM/S

MEAN Y COMPONENT = -8.20 CM/S STANDARD DEVIATION = 13.61 CM/S

MAXIMUM = 80.11 CM/S

MAXIMUM = 58.93 CM/S

MINIMUM = -72.44 CM/S

MINIMUM = -75.96 CM/S

Table A-1. Bivariate Statistics of hourly currents.  
(b) Deployment A at 100 m depth.

# **FREQUENCY DISTRIBUTION**

STATION: 106-Mile Site Real-Time Moorin S/N: 223 INSTRUMENT DEPTH: 100.0 WATER DEPTH: 2600.0  
FILENAME: m6ma23 FROM: 01/20/89 TO: 09/13/89 5668 DATA POINTS

DIRECTION TOWARDS  
DEGREES

SUM PERCENT

-0- 30	22	15	27	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	72	1.3
30- 60	14	21	20	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	65	1.1
60- 90	17	25	21	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70	1.2
90-120	15	16	20	10	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63	1.1
120-150	16	29	22	38	10	19	20	31	33	23	20	16	15	8	6	20	9	4	0	0	0	339	6.0
150-180	26	69	68	47	51	49	65	38	63	40	23	13	12	3	8	7	10	18	3	0	0	613	10.8
180-210	32	86	110	138	93	64	57	36	28	9	4	1	2	0	0	0	0	0	0	0	0	660	11.6
210-240	39	153	220	221	138	75	48	12	4	0	0	0	0	0	0	0	0	0	0	0	0	910	16.1
240-270	45	190	266	274	174	71	47	31	20	13	18	8	0	0	0	0	0	0	0	0	0	1157	20.4
270-300	38	123	192	209	96	37	27	34	46	37	32	18	4	0	0	0	0	0	0	0	0	893	15.8
300-330	23	67	82	100	84	58	40	32	24	4	6	10	28	31	21	7	4	0	0	0	0	621	11.0
330-360	25	47	45	43	26	18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	205	3.6

SPEED	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95		
CM/S																						
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100		

SUM	312	841	1093	1105	673	392	305	214	218	126	103	66	61	42	35	34	23	22	3	0	5668
PERCENT	5.5	14.8	19.3	19.5	11.9	6.9	5.4	3.8	3.8	2.2	1.8	1.2	1.1	0.7	0.6	0.6	0.4	0.4	0.1	0.0	
CUM PRCT	100.0	94.5	79.7	60.4	40.9	29.0	22.1	16.7	12.9	9.1	6.9	5.0	3.9	2.8	2.1	1.4	0.8	0.4	0.1	0.0	

## **SUMMARY STATISTICS**

MEAN VELOCITY = 11.22 CM/S TOWARD 235 DEG T

MEAN EAST COMPONENT = -9.14 CM/S STANDARD DEVIATION = 16.29 CM/S

MAXIMUM = 52.88 CM/S

MINIMUM = -67.77 CM/S

MEAN NORTH COMPONENT = -6.51 CM/S STANDARD DEVIATION = 18.51 CM/S

MAXIMUM = 59.85 CM/S

MINIMUM = -88.02 CM/S

MEAN SPEED = 21.96 CM/S STANDARD DEVIATION = 15.86 CM/S

MAXIMUM = 93.15 CM/S

MINIMUM = 0.00 CM/S

IN A COORDINATE SYSTEM WHOSE Y AXIS IS DIRECTED TOWARD 45 DEGREES TRUE

MEAN X COMPONENT = -1.86 CM/S STANDARD DEVIATION = 22.29 CM/S

MAXIMUM = 86.12 CM/S

MINIMUM = -82.98 CM/S

MEAN Y COMPONENT = -11.07 CM/S STANDARD DEVIATION = 10.55 CM/S

MAXIMUM = 18.66 CM/S

MINIMUM = -50.89 CM/S

(c) Deployment B at 100 m depth.

**FREQUENCY DISTRIBUTION**

STATION: 106-Mile Site Real-Time Moorin S/N: 223 INSTRUMENT DEPTH: 100.0 WATER DEPTH: 2600.0

FILENAME: m6mb23

FROM: 10/13/89 TO: 01/17/90

2292 DATA POINTS

DIRECTION TOWARDS

DEGREES

SUM PERCENT

-0- 30	4	6	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0.7
30- 60	4	7	3	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0.8
60- 90	6	4	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0.7
90-120	7	12	7	3	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	1.5
120-150	14	12	7	8	2	1	4	5	2	6	2	2	1	0	0	0	0	0	0	0	0	66	2.9
150-180	8	27	35	15	6	9	5	3	4	2	1	5	2	1	0	0	0	0	0	0	0	123	5.4
180-210	12	43	59	69	58	41	21	15	3	0	0	0	0	0	0	0	0	0	0	0	0	321	14.0
210-240	10	45	107	117	123	105	61	31	27	5	3	0	0	0	0	0	0	0	0	0	0	634	27.7
240-270	17	69	111	132	97	69	43	23	18	10	2	0	0	0	0	0	0	0	0	0	0	591	25.8
270-300	9	54	51	61	33	29	13	6	0	9	11	9	4	3	1	0	0	0	0	0	0	293	12.8
300-330	13	19	33	22	13	7	2	3	7	7	6	2	2	1	2	0	0	0	0	0	0	139	6.1
330-360	12	11	6	6	5	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	1.9

SPEED	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95		
CM/S																						
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100		

SUM	116	309	423	440	343	265	150	86	61	39	25	18	9	5	3	0	0	0	0	0	2292
PERCENT	5.1	13.5	18.5	19.2	15.0	11.6	6.5	3.8	2.7	1.7	1.1	0.8	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	
CUM PRCT	100.0	94.9	81.5	63.0	43.8	28.8	17.3	10.7	7.0	4.3	2.6	1.5	0.7	0.3	0.1	0.0	0.0	0.0	0.0	0.0	

**SUMMARY STATISTICS**

MEAN VELOCITY = 15.12 CM/S TOWARD 239 DEG T

MEAN EAST COMPONENT = -12.96 CM/S STANDARD DEVIATION = 12.82 CM/S

MAXIMUM = 33.28 CM/S

MINIMUM = -65.48 CM/S

MEAN NORTH COMPONENT = -7.79 CM/S STANDARD DEVIATION = 12.73 CM/S

MAXIMUM = 43.42 CM/S

MINIMUM = -60.45 CM/S

MEAN SPEED = 20.35 CM/S STANDARD DEVIATION = 11.88 CM/S

MAXIMUM = 74.41 CM/S

MINIMUM = 0.63 CM/S

IN A COORDINATE SYSTEM WHOSE Y AXIS IS DIRECTED TOWARD 45 DEGREES TRUE

MEAN X COMPONENT = -3.65 CM/S STANDARD DEVIATION = 14.17 CM/S

MAXIMUM = 60.75 CM/S

MINIMUM = -71.79 CM/S

MEAN Y COMPONENT = -14.68 CM/S STANDARD DEVIATION = 11.21 CM/S

MAXIMUM = 21.10 CM/S

MINIMUM = -52.19 CM/S

(d) Deployment D at 25 m depth.

# FREQUENCY DISTRIBUTION

STATION: 106-Mile Site Real-Time Moorin S/N: 122 INSTRUMENT DEPTH: 25.0 WATER DEPTH: 2600.0  
 FILENAME: m6md22 FROM: 07/20/90 TO: 09/26/90 1646 DATA POINTS

DIRECTION TOWARDS  
 DEGREES

																					SUM	PERCENT
-0- 30	12	11	10	6	5	2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	48	2.9
30- 60	8	13	4	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	1.8
60- 90	16	9	1	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	2.1
90-120	7	15	6	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	33	2.0
120-150	12	14	11	8	1	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	50	3.0
150-180	10	27	19	16	12	3	2	6	0	0	0	0	0	0	0	0	0	0	0	0	95	5.8
180-210	21	35	46	28	31	11	9	7	3	1	0	0	0	0	0	0	0	0	0	0	192	11.7
210-240	18	54	53	62	47	31	21	11	6	2	0	0	0	0	0	0	0	0	0	0	305	18.5
240-270	18	50	70	58	75	61	44	19	11	0	0	0	0	0	0	0	0	0	0	0	406	24.7
270-300	12	47	38	49	50	27	20	9	5	1	0	0	0	0	0	0	0	0	0	0	258	15.7
300-330	19	22	26	20	17	9	6	5	4	0	2	0	0	0	0	0	0	0	0	0	130	7.9
330-360	14	20	7	9	6	2	2	1	1	1	0	1	0	0	0	0	0	0	0	0	64	3.9
SPEED	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95		
CM/S																						
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100		
SUM	167	317	291	269	247	148	109	59	31	5	2	1	0	0	0	0	0	0	0	0	1646	
PERCENT	10.1	19.3	17.7	16.3	15.0	9.0	6.6	3.6	1.9	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
CUM PRCT	100.0	89.9	70.6	52.9	36.6	21.6	12.6	6.0	2.4	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

## SUMMARY STATISTICS

MEAN VELOCITY = 11.40 CM/S TOWARD 250 DEG T

MEAN EAST COMPONENT = -10.75 CM/S STANDARD DEVIATION = 11.88 CM/S

MAXIMUM = 29.49 CM/S

MINIMUM = -45.13 CM/S

MEAN NORTH COMPONENT = -3.81 CM/S STANDARD DEVIATION = 11.31 CM/S

MAXIMUM = 54.83 CM/S

MINIMUM = -41.84 CM/S

MEAN SPEED = 17.19 CM/S STANDARD DEVIATION = 10.18 CM/S

MAXIMUM = 56.62 CM/S

MINIMUM = 0.28 CM/S

IN A COORDINATE SYSTEM WHOSE Y AXIS IS DIRECTED TOWARD 45 DEGREES TRUE

MEAN X COMPONENT = -4.90 CM/S STANDARD DEVIATION = 11.67 CM/S

MAXIMUM = 36.58 CM/S

MINIMUM = -52.81 CM/S

MEAN Y COMPONENT = -10.30 CM/S STANDARD DEVIATION = 11.54 CM/S

MAXIMUM = 35.41 CM/S

MINIMUM = -48.69 CM/S

Table A-2: Bivariate statistics of low pass filtered currents.  
(a) Deployment A at 25 m depth.

# FREQUENCY DISTRIBUTION

STATION: 106-Mile Site Real-Time Moorin S/N: 372 INSTRUMENT DEPTH: 25.0 WATER DEPTH: 2600.0  
FILENAME: m6ma72 FROM: 01/20/89 TO: 09/13/89 5104 DATA POINTS

DIRECTION TOWARDS  
DEGREES

																					SUM	PERCENT
-0- 30	12	57	13	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	103	2.0
30- 60	2	18	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0.6
60- 90	3	12	23	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61	1.2
90-120	2	24	11	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	41	0.8
120-150	17	32	8	8	6	2	0	8	4	0	0	0	0	0	0	0	0	0	0	0	85	1.7
150-180	21	91	23	13	23	30	70	37	26	15	6	5	43	12	18	8	0	0	0	0	441	8.6
180-210	56	84	36	104	72	34	97	20	29	7	6	7	2	0	0	0	0	0	0	0	554	10.9
210-240	43	111	178	129	69	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	559	11.0
240-270	51	328	480	229	62	39	0	23	0	0	0	0	0	0	0	0	0	0	0	0	1212	23.7
270-300	90	429	345	70	58	3	7	62	30	25	4	0	0	0	0	0	0	0	0	0	1123	22.0
300-330	39	134	200	26	61	17	44	20	25	24	27	20	7	0	0	0	0	0	0	0	644	12.6
330-360	17	53	49	47	6	6	0	0	0	0	0	9	39	23	0	0	0	0	0	0	249	4.9
SPEED	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95		
CM/S																						
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100		
SUM	353	1373	1378	674	357	160	218	170	114	71	43	41	91	35	18	8	0	0	0	0	5104	
PERCENT	6.9	26.9	27.0	13.2	7.0	3.1	4.3	3.3	2.2	1.4	0.8	0.8	1.8	0.7	0.4	0.2	0.0	0.0	0.0	0.0		
CUM PRCT	100.0	93.1	66.2	39.2	26.0	19.0	15.9	11.6	8.2	6.0	4.6	3.8	3.0	1.2	0.5	0.2	0.0	0.0	0.0	0.0		

## SUMMARY STATISTICS

MEAN VELOCITY = 9.24 CM/S TOWARD 252 DEG T

MEAN EAST COMPONENT = -8.80 CM/S STANDARD DEVIATION = 14.37 CM/S

MEAN NORTH COMPONENT = -2.79 CM/S STANDARD DEVIATION = 19.44 CM/S

MEAN SPEED = 20.91 CM/S STANDARD DEVIATION = 15.25 CM/S

MAXIMUM = 53.41 CM/S

MAXIMUM = 70.64 CM/S

MAXIMUM = 83.65 CM/S

MINIMUM = -63.48 CM/S

MINIMUM = -77.01 CM/S

MINIMUM = 0.02 CM/S

IN A COORDINATE SYSTEM WHOSE Y AXIS IS DIRECTED TOWARD 45 DEGREES TRUE

MEAN X COMPONENT = -4.25 CM/S STANDARD DEVIATION = 19.98 CM/S

MEAN Y COMPONENT = -8.20 CM/S STANDARD DEVIATION = 13.61 CM/S

MAXIMUM = 80.11 CM/S

MAXIMUM = 58.93 CM/S

MINIMUM = -72.44 CM/S

MINIMUM = -75.96 CM/S

Table A-2. Bivariate statistics of low-pass-filtered currents.  
(b) Deployment A at 100 m depth.

# **FREQUENCY DISTRIBUTION**

STATION: 106-Mile Site Real-Time Moorin S/N: 223 INSTRUMENT DEPTH: 100.0 WATER DEPTH: 2600.0  
FILENAME: m6ma23 FROM: 01/20/89 TO: 09/13/89 5668 DATA POINTS

DIRECTION TOWARDS  
DEGREES

																					SUM	PERCENT
-0- 30	9	13	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	42	0.7
30- 60	3	21	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	53	0.9
60- 90	0	27	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	0.8
90-120	5	27	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0.9
120-150	20	16	17	21	13	13	15	20	39	30	20	11	11	16	14	15	7	0	0	0	298	5.3
150-180	42	19	78	6	35	49	62	25	80	48	12	9	10	14	9	4	9	19	0	0	530	9.4
180-210	61	100	154	103	106	46	49	65	22	0	0	0	0	0	0	0	0	0	0	0	706	12.5
210-240	29	192	295	282	98	20	41	0	0	0	0	0	0	0	0	0	0	0	0	0	957	16.9
240-270	38	305	473	301	173	27	23	15	18	23	23	0	0	0	0	0	0	0	0	0	1419	25.0
270-300	19	164	315	87	43	24	17	53	82	50	8	7	6	0	0	0	0	0	0	0	875	15.4
300-330	7	48	67	187	72	17	23	28	20	4	5	5	13	52	30	0	0	0	0	0	578	10.2
330-360	26	21	17	46	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	117	2.1
SPEED	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95		
CM/S																						
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100		
SUM	259	953	1499	1033	547	196	230	206	261	155	68	32	40	82	53	19	16	19	0	0	5668	
PERCENT	4.6	16.8	26.4	18.2	9.7	3.5	4.1	3.6	4.6	2.7	1.2	0.6	0.7	1.4	0.9	0.3	0.3	0.3	0.0	0.0		
CUM PRCT	100.0	95.4	78.6	52.2	33.9	24.3	20.8	16.8	13.1	8.5	5.8	4.6	4.0	3.3	1.9	1.0	0.6	0.3	0.0	0.0		

# **SUMMARY STATISTICS**

MEAN VELOCITY = 11.22 CM/S TOWARD 235 DEG T

MEAN EAST COMPONENT = -9.14 CM/S STANDARD DEVIATION = 16.29 CM/S

MAXIMUM = 52.88 CM/S

MINIMUM = -67.77 CM/S

MEAN NORTH COMPONENT = -6.51 CM/S STANDARD DEVIATION = 18.51 CM/S

MAXIMUM = 59.85 CM/S

MINIMUM = -88.02 CM/S

MEAN SPEED = 21.96 CM/S STANDARD DEVIATION = 15.86 CM/S

MAXIMUM = 93.15 CM/S

MINIMUM = 0.00 CM/S

IN A COORDINATE SYSTEM WHOSE Y AXIS IS DIRECTED TOWARD 45 DEGREES TRUE

MEAN X COMPONENT = -1.86 CM/S STANDARD DEVIATION = 22.29 CM/S

MAXIMUM = 86.12 CM/S

MINIMUM = -82.98 CM/S

MEAN Y COMPONENT = -11.07 CM/S STANDARD DEVIATION = 10.55 CM/S

MAXIMUM = 18.66 CM/S

MINIMUM = -50.89 CM/S

(c) Deployment B at 100 m depth.

## FREQUENCY DISTRIBUTION

STATION: 106-Mile Site Real-Time Moorin S/N: 223 INSTRUMENT DEPTH: 100.0 WATER DEPTH: 2600.0  
 FILENAME: m6mb23 FROM: 10/13/89 TO: 01/17/90 2292 DATA POINTS

### DIRECTION TOWARDS

DEGREES																					SUM	PERCENT
-0- 30	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0.3
30- 60	2	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0.3
60- 90	8	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	1.0
90-120	5	3	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	1.3
120-150	3	3	7	0	0	0	0	2	4	5	9	0	0	0	0	0	0	0	0	0	33	1.4
150-180	3	7	0	5	4	8	8	6	4	5	4	0	0	0	0	0	0	0	0	0	54	2.4
180-210	1	31	56	18	43	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	155	6.8
210-240	14	75	248	147	158	163	109	34	0	0	0	0	0	0	0	0	0	0	0	0	948	41.4
240-270	17	178	224	136	44	67	39	4	0	0	0	0	0	0	0	0	0	0	0	0	709	30.9
270-300	2	52	73	46	26	15	11	6	5	5	7	23	0	0	0	0	0	0	0	0	271	11.8
300-330	1	0	13	0	0	0	0	3	5	5	6	8	0	0	0	0	0	0	0	0	41	1.8
330-360	0	3	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0.6
SPEED	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95		
CM/S																						
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100		
SUM	56	379	654	352	275	259	167	55	18	20	26	31	0	0	0	0	0	0	0	0	2292	
PERCENT	2.4	16.5	28.5	15.4	12.0	11.3	7.3	2.4	0.8	0.9	1.1	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
CUM PRCT	100.0	97.6	81.0	52.5	37.1	25.1	13.8	6.5	4.1	3.4	2.5	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

## SUMMARY STATISTICS

MEAN VELOCITY = 15.12 CM/S TOWARD 239 DEG T

MEAN EAST COMPONENT = -12.96 CM/S	STANDARD DEVIATION = 12.82 CM/S	MAXIMUM = 33.28 CM/S	MINIMUM = -65.48 CM/S
MEAN NORTH COMPONENT = -7.79 CM/S	STANDARD DEVIATION = 12.73 CM/S	MAXIMUM = 43.42 CM/S	MINIMUM = -60.45 CM/S
MEAN SPEED = 20.35 CM/S	STANDARD DEVIATION = 11.88 CM/S	MAXIMUM = 74.41 CM/S	MINIMUM = 0.63 CM/S

IN A COORDINATE SYSTEM WHOSE Y AXIS IS DIRECTED TOWARD 45 DEGREES TRUE

MEAN X COMPONENT = -3.65 CM/S	STANDARD DEVIATION = 14.17 CM/S	MAXIMUM = 60.75 CM/S	MINIMUM = -71.79 CM/S
MEAN Y COMPONENT = -14.68 CM/S	STANDARD DEVIATION = 11.21 CM/S	MAXIMUM = 21.10 CM/S	MINIMUM = -52.19 CM/S

**FREQUENCY DISTRIBUTION**

STATION: 106-Mile Site Real-Time Moorin S/N: 122 INSTRUMENT DEPTH: 25.0 WATER DEPTH: 2600.0

FILENAME: m6md22

FROM: 07/20/90 TO: 09/26/90

1646 DATA POINTS

DIRECTION TOWARDS

DEGREES

SUM PERCENT

-0- 30	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.1
30- 60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
60- 90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
90-120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
120-150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
150-180	12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0.8
180-210	43	26	29	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	105	6.4
210-240	115	104	132	34	55	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	455	27.6
240-270	44	77	317	211	117	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	766	46.5
270-300	8	89	145	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	267	16.2
300-330	2	0	5	20	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	2.2
330-360	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0.2

SPEED	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	
CM/S																					
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	

SUM	228	297	628	297	181	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1646
PERCENT	13.9	18.0	38.2	18.0	11.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
CUM PRCT	100.0	86.1	68.1	30.0	11.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

**SUMMARY STATISTICS**

MEAN VELOCITY = 11.40 CM/S TOWARD 250 DEG T

MEAN EAST COMPONENT = -10.75 CM/S STANDARD DEVIATION = 11.88 CM/S

MAXIMUM = 29.49 CM/S

MINIMUM = -45.13 CM/S

MEAN NORTH COMPONENT = -3.81 CM/S STANDARD DEVIATION = 11.31 CM/S

MAXIMUM = 54.83 CM/S

MINIMUM = -41.84 CM/S

MEAN SPEED = 17.19 CM/S STANDARD DEVIATION = 10.18 CM/S

MAXIMUM = 56.62 CM/S

MINIMUM = 0.28 CM/S

IN A COORDINATE SYSTEM WHOSE Y AXIS IS DIRECTED TOWARD 45 DEGREES TRUE

MEAN X COMPONENT = -4.90 CM/S STANDARD DEVIATION = 11.67 CM/S

MAXIMUM = 36.58 CM/S

MINIMUM = -52.81 CM/S

MEAN Y COMPONENT = -10.30 CM/S STANDARD DEVIATION = 11.54 CM/S

MAXIMUM = 35.41 CM/S

MINIMUM = -48.69 CM/S

Table A-3. Bivariate statistics of hourly wind velocity for deployments C and D through September 1990.

**FREQUENCY DISTRIBUTION**

STATION: 106-Mile Site Real-Time Moorin S/N: 0 INSTRUMENT DEPTH: 0.0 WATER DEPTH: 2600.0  
 FILENAME: metc FROM: 02/06/90 TO: 09/27/90 5567 DATA POINTS

DIRECTION TOWARDS  
 DEGREES

																					SUM	PERCENT
-0- 30	212	129	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	348	6.3
30- 60	339	386	61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	786	14.1
60- 90	392	436	91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	919	16.5
90-120	322	280	42	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	647	11.6
120-150	223	291	77	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	604	10.8
150-180	192	311	50	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	556	10.0
180-210	152	272	73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	497	8.9
210-240	170	142	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	330	5.9
240-270	141	103	23	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	268	4.8
270-300	102	74	7	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	186	3.3
300-330	102	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	177	3.2
330-360	147	101	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	249	4.5
SPEED	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95		
M/S																						
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100		
SUM	2494	2600	450	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5567	
PERCENT	44.8	46.7	8.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
CUM PRCT	100.0	55.2	8.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

**SUMMARY STATISTICS**

MEAN VELOCITY = 2.12 M/S TOWARD 109 DEG T

MEAN EAST COMPONENT = 2.00 M/S STANDARD DEVIATION = 4.23 M/S

MEAN NORTH COMPONENT = -0.70 M/S STANDARD DEVIATION = 4.34 M/S

MEAN SPEED = 5.76 M/S STANDARD DEVIATION = 2.83 M/S

MAXIMUM = 14.34 M/S

MAXIMUM = 11.88 M/S

MAXIMUM = 16.88 M/S

MINIMUM = -16.42 M/S

MINIMUM = -13.97 M/S

MINIMUM = 0.24 M/S

IN A COORDINATE SYSTEM WHOSE Y AXIS IS DIRECTED TOWARD 45 DEGREES TRUE

MEAN X COMPONENT = 1.91 M/S STANDARD DEVIATION = 3.96 M/S

MEAN Y COMPONENT = 0.92 M/S STANDARD DEVIATION = 4.59 M/S

MAXIMUM = 16.11 M/S

MAXIMUM = 13.73 M/S

MINIMUM = -14.56 M/S

MINIMUM = -12.76 M/S

Table A-4. Tidal analysis results in current ellipse form from current measurements.  
(a) Deployment A at 100 m depth.

FOR STATION a23, 106-MILE SITE MOORING  
OVER THE PERIOD OF 1HR 21/ 1/89 TO 24HR 12/ 9/89

NODAL MODULATION AND INFERENCE CORRECTIONS HAVE BEEN MADE  
GREENWICH PHASES ARE FOR TIME ZONE EST

NAME	SPEED	MAJOR	MINOR	INC	G	G+	G-
1 Z0	.00000000	10.926	.000	37.2	180.0	142.8	217.2
2 SSA	.00022816	2.687	1.374	77.2	157.4	80.2	234.6
3 MSM	.00130978	10.722	-1.425	119.3	268.4	149.2	27.7
4 MM	.00151215	5.381	-.655	103.7	104.4	.7	208.1
5 MSF	.00282193	2.800	.847	.9	5.6	4.7	6.4
6 MF	.00305009	3.811	1.110	159.3	39.7	240.4	199.0
7 ALP1	.03439657	.079	-.005	14.2	314.6	300.4	328.7
8 ZQ1	.03570635	.254	-.024	17.2	108.4	91.1	125.6
9 SIG1	.03590872	.141	-.085	94.5	10.5	276.1	105.0
10 Q1	.03721850	.166	.096	161.5	98.8	297.3	260.2
11 RH01	.03742087	.220	-.033	123.1	131.9	8.7	255.0
12 O1	.03873065	.218	.105	105.5	64.8	319.3	170.3
13 TAU1	.03895881	.492	-.075	134.4	193.0	58.6	327.5
14 BET1	.04004044	.178	-.031	35.4	276.4	241.0	311.8
15 NO1	.04026860	.223	-.150	145.4	8.0	222.7	153.4
16 CH11	.04047097	.254	.148	54.5	234.2	179.8	288.7
17 P1	.04155259	.319	-.036	98.2	288.3	190.1	26.5
18 K1	.04178075	.449	-.212	111.2	185.7	74.5	296.9
19 PH11	.04200891	.114	.030	115.3	268.4	153.1	23.6
20 THE1	.04309053	.214	-.095	104.4	229.6	125.1	334.0
21 J1	.04329290	.213	.153	67.2	194.2	127.0	261.3
22 SO1	.04460268	.137	.066	145.1	149.6	4.4	294.7
23 QO1	.04483084	.157	-.058	81.7	321.7	239.9	43.4
24 UPS1	.04634299	.330	-.152	24.1	77.3	53.2	101.4
25 QO2	.07597495	.242	.063	105.3	111.9	6.6	217.2
26 EPS2	.07617731	.269	.059	167.8	35.7	227.9	203.5
27 ZN2	.07748710	.172	-.043	30.3	269.4	239.1	299.7
28 MU2	.07768947	.263	-.103	175.0	178.1	3.1	353.1
29 N2	.07899925	.711	-.374	11.7	235.3	223.5	247.0
30 NU2	.07920162	.486	-.376	80.6	270.5	190.0	351.1
31 M2	.08051140	1.598	-.256	143.4	40.5	257.1	184.0
32 MKS2	.08073956	.447	-.190	117.9	93.9	336.0	211.8
33 LDA2	.08182118	.496	-.292	.7	221.1	220.4	221.8
34 L2	.08202355	.518	-.392	86.7	300.6	213.9	27.2
35 S2	.08333334	.445	-.040	96.3	31.5	295.3	127.8
36 K2	.08356149	.448	-.388	114.1	51.9	297.9	166.0
37 MSN2	.08484548	.437	-.221	68.3	322.6	254.3	30.9
38 ETA2	.08507364	.277	-.259	103.4	103.1	359.7	206.4
39 MO3	.11924210	.140	-.032	5.1	123.2	118.1	128.2
40 M3	.12076710	.182	-.018	178.7	171.8	353.1	350.4
41 SO3	.12206400	.127	-.074	110.4	304.0	193.6	54.4
42 MK3	.12229210	.115	.021	161.6	40.0	238.4	201.6
43 SK3	.12511410	.118	-.064	19.9	52.5	32.6	72.4
44 MN4	.15951060	.070	.009	60.6	116.9	56.3	177.5
45 M4	.16102280	.164	-.067	82.1	55.1	333.1	137.2
46 SN4	.16233260	.134	-.008	73.7	64.3	350.5	138.0
47 MS4	.16384470	.183	-.014	26.9	169.7	142.8	196.6
48 MK4	.16407290	.124	-.015	88.5	124.2	35.7	212.7
49 S4	.16666670	.053	-.003	114.8	234.5	119.7	349.4
50 SK4	.16689480	.092	-.043	118.9	279.7	160.8	38.6
51 2MK5	.20280360	.071	-.037	127.0	243.7	116.7	10.7
52 2SK5	.20844740	.063	-.012	135.0	231.5	96.5	6.6
53 2MN6	.24002200	.120	.008	41.2	30.3	349.1	71.6
54 M6	.24153420	.100	.048	29.6	48.3	18.7	77.9
55 2MS6	.24435610	.104	-.040	148.8	197.8	49.0	346.5
56 2MK6	.24458430	.053	-.029	158.7	252.8	94.2	51.5
57 2SM6	.24717810	.079	-.031	3.8	313.9	310.0	317.7
58 MSK6	.24740620	.123	-.007	79.8	306.7	226.9	26.5
59 3MK7	.28331490	.081	.024	168.1	195.8	27.7	3.9
60 M8	.32204560	.054	.000	7.1	288.6	281.6	295.7

Table A-4. Tidal analysis results in current ellipse form from current measurements.  
(b) Deployment B at 100 m depth.

FOR STATION b23, 106-MILE SITE MOORING  
OVER THE PERIOD OF 1HR 14/10/89 TO 24HR 16/ 1/90

NODAL MODULATION AND INFERENCE CORRECTIONS HAVE BEEN MADE  
GREENWICH PHASES ARE FOR TIME ZONE EST

NAME	SPEED	MAJOR	MINOR	INC	G	G+	G-
1 Z0	.00000000	15.678	.000	32.0	180.0	148.0	212.0
2 MM	.00151215	6.439	4.053	39.0	71.7	32.7	110.7
3 MSF	.00282193	6.485	-.275	134.2	4.2	230.0	138.5
4 ALP1	.03439657	.326	.045	144.6	329.3	184.6	113.9
5 2Q1	.03570635	.453	.179	146.2	181.7	35.4	327.9
6 Q1	.03721850	.773	-.467	154.2	61.1	266.8	215.3
7 O1	.03873065	.724	-.225	164.0	21.3	217.3	185.3
8 NO1	.04026860	.274	.081	59.1	107.3	48.1	166.4
9 P1	.04155259	.201	-.105	179.1	257.1	78.0	76.2 INF FR K1
10 K1	.04178075	.930	-.620	1.2	74.7	73.5	76.0
11 J1	.04329290	.235	.024	149.9	26.4	236.5	176.3
12 O01	.04483084	.513	-.084	144.4	320.3	175.9	104.7
13 UPS1	.04634299	.524	-.222	27.7	181.8	154.2	209.5
14 EPS2	.07617731	.377	-.025	144.5	231.8	87.3	16.3
15 MU2	.07768947	.921	-.661	152.1	336.9	184.7	129.0
16 N2	.07899925	1.471	-1.155	170.7	334.7	163.9	145.4
17 M2	.08051140	2.234	-.902	107.3	352.7	245.4	100.0
18 L2	.08202355	.679	-.011	132.1	241.4	109.3	13.5
19 S2	.08333334	.893	-.496	140.5	26.3	245.8	166.8
20 K2	.08356149	.186	-.110	119.5	20.1	260.6	139.6 INF FR S2
21 ETA2	.08507364	.198	-.053	5.6	5.4	359.8	11.0
22 M03	.11924210	.308	-.146	69.9	34.7	324.8	104.6
23 M3	.12076710	.127	-.056	76.7	322.0	245.3	38.7
24 MK3	.12229210	.232	-.044	36.8	177.2	140.5	214.0
25 SK3	.12511410	.168	.085	113.3	1.1	247.8	114.5
26 MN4	.15951060	.284	-.104	58.9	201.1	142.2	259.9
27 M4	.16102280	.194	-.017	85.1	104.6	19.5	189.8
28 SN4	.16233260	.192	.048	104.8	320.2	215.4	65.0
29 MS4	.16384470	.085	.019	98.4	154.2	55.8	252.5
30 S4	.16666670	.179	-.033	10.9	182.2	171.3	193.1
31 2MK5	.20280360	.150	.021	131.5	79.2	307.7	210.7
32 2SK5	.20844740	.121	.018	70.3	161.5	91.2	231.8
33 2MN6	.24002200	.144	.077	146.0	323.5	177.5	109.5
34 M6	.24153420	.079	-.010	77.9	139.5	61.6	217.4
35 2MS6	.24435610	.147	-.058	116.3	95.5	339.2	211.7
36 2SM6	.24717810	.212	-.131	52.9	311.4	258.6	4.3
37 3MK7	.28331490	.204	-.088	15.2	307.2	291.9	322.4
38 M8	.32204560	.144	-.038	41.1	119.6	78.5	160.6

Table A-4. Tidal analysis results in current ellipse form from current measurements.  
(c) Deployment D at 25 m depth.

FOR STATION d22, 106-MILE SITE MOORING  
OVER THE PERIOD OF 1HR 21/ 7/90 TO 12HR 26/ 9/90

NODAL MODULATION AND INFERENCE CORRECTIONS HAVE BEEN MADE  
GREENWICH PHASES ARE FOR TIME ZONE EST

NAME	SPEED	MAJOR	MINOR	INC	G	G+	G-	
1 Z0	.00000000	11.978	.000	19.6	180.0	160.4	199.6	
2 MM	.00151215	3.898	1.364	18.0	138.3	120.3	156.3	
3 MSF	.00282193	1.939	1.602	158.3	99.1	300.9	257.4	
4 ALP1	.03439657	.456	-.231	141.6	71.2	289.6	212.8	
5 2Q1	.03570635	.503	-.191	175.4	155.0	339.6	330.4	
6 Q1	.03721850	.780	-.540	1.4	281.0	279.6	282.4	
7 O1	.03873065	.706	-.461	19.7	238.7	219.0	258.4	
8 NO1	.04026860	.808	-.536	15.6	178.9	163.3	194.5	
9 P1	.04155259	.212	-.098	113.9	103.5	349.7	217.4	INF FR K1
10 K1	.04178075	.969	-.602	116.0	101.2	345.2	217.2	
11 J1	.04329290	.224	.046	160.3	138.8	338.5	299.1	
12 O01	.04483084	1.011	-.818	162.9	40.8	237.9	203.7	
13 UPS1	.04634299	.798	-.613	60.3	60.6	.3	120.9	
14 EPS2	.07617731	1.243	-1.095	1.9	109.9	108.0	111.9	
15 MU2	.07768947	.594	-.462	51.9	134.1	82.2	186.1	
16 N2	.07899925	1.310	-.995	104.7	33.4	288.7	138.1	
17 M2	.08051140	4.425	-2.247	130.5	3.1	232.6	133.5	
18 L2	.08202355	2.317	-1.312	179.7	122.7	303.1	302.4	
19 S2	.08333334	3.157	-2.077	143.4	88.1	304.8	231.5	
20 K2	.08356149	.660	-.453	122.4	81.9	319.6	204.3	INF FR S2
21 ETA2	.08507364	.640	-.177	3.2	263.1	259.9	266.2	
22 MO3	.11924210	.347	-.202	140.1	231.2	91.0	11.3	
23 M3	.12076710	.186	-.114	100.0	287.1	187.1	27.1	
24 MK3	.12229210	.513	-.127	66.8	235.9	169.1	302.6	
25 SK3	.12511410	.261	.032	162.0	88.5	286.5	250.5	
26 MN4	.15951060	.328	-.070	171.9	29.7	217.9	201.6	
27 M4	.16102280	.527	-.199	118.8	87.3	328.4	206.1	
28 SN4	.16233260	.262	.074	106.7	265.7	159.0	12.4	
29 MS4	.16384470	.656	-.238	160.6	109.6	308.9	270.2	
30 S4	.16666670	.105	-.043	133.3	251.2	117.8	24.5	
31 ZMK5	.20280360	.136	-.099	165.2	141.7	336.5	306.8	
32 ZSK5	.20844740	.161	-.131	73.3	80.2	6.9	153.5	
33 ZMN6	.24002200	.183	-.101	40.8	267.6	226.7	308.4	
34 M6	.24153420	.211	.043	96.1	122.5	26.4	218.7	
35 ZMS6	.24435610	.246	-.123	17.1	117.9	100.8	135.1	
36 ZSM6	.24717810	.189	.001	133.8	298.9	165.1	72.7	
37 ZMK7	.28331490	.165	-.046	67.5	3.4	295.9	71.0	
38 M8	.32204560	.229	-.015	120.9	100.9	340.0	221.8	